Abstract Submitted
for the DAMOP17 Meeting of
The American Physical Society

Bosonic Particle-Correlated States: A Nonperturbative Treatment Beyond Mean Field ZHANG JIANG, NASA/Ames Res Ctr, ALEXANDRE TACLA, Department of Physics and SUPA, University of Strathclyde, CARLTON CAVES, Center for Quantum Information and Control, University of New Mexico — We consider a natural generalization of the product ansatz for Bose-Einstein condensates; the particle-correlated state of $N = l \times n$ identical particles is derived by symmetrizing the n-fold product of an l-particle quantum state. Quantum correlations of the l-particle state "spread out" to any subset of the N particles by symmetrization. The particle-correlated states can be simulated efficiently for large N, because their parameter spaces, which depend on l, do not grow with n. We pay special attention to the pure-state case for $l = 2$, where the many-body state is constructed from a two-particle pure state. These paired wave functions were introduced by Leggett [Rev. Mod. Phys. **73**, 307 (2001)] as a particle-number-conserving version of the Bogoliubov approximation. For large N, we derive few-particle reduced density matrices (correlation functions) for these wave functions. To test the efficacy of our theory, we solve the two-site Bose-Hubbard model by minimizing the energy using the two-particle reduced density matrices that we derived analytically. We find that the relative errors of the ground state energy are within 10^{-5} for $N = 1000$ particles over the entire range from a single condensate to a Mott insulator.

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Date submitted: 06 Apr 2017

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