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Nonlinear mean-field versus linear quantum electrodynamics descriptions of a two-particle interacting bound-state quantum system

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The nonlinear mean-field quantum model consists in an isotropic singlet pair of opposite-spin electrons confined in an external harmonic potential. The S=0 zero spins of the pair close the Schrödinger-Poisson (SP) differential system by assuming that the two electrons belong to the same orbital state in accordance with the Pauli principle. The choice of the harmonic potential agrees with the generalized Kohn theorem stating that the center-of-mass and the internal degrees of freedom of a parabolically-confined many-particle interacting quantum system are completely decoupled. Indeed we are only interested in the internal structure of the two-particle wave function. Therefore the parabolic confinement ensures that there will not be any perturbation of this internal state by its external center-of-mass degree of freedom. The mean-field stationary SP model makes an explicit use of the classical electrostatic Poisson equation. Its quantum electrodynamics (QED) counterpart consists in the lowest-order single virtual—actually"scalar"—photon exchange between two fixed charges. In order to transpose this classical-like QED description to our mean-field quantum model, we replace the two classical point-like charge distributions in the QED Hamiltonian by the corresponding SP charge densities. While computing numerically it is being observed that the ground state and the first excited state of nonlinear SP differential system about their maximum eigenstate overlap (non-zero because of eigenstate non-orthogonality due to SP's intrinsic nonlinearity), then numerically it was demonstrated that these two descriptions coincide at first order. As a result, a specific definition of the fine-structure constant is provided within a 99.95% accuracy.

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