Linear-response formalism in density-functional theory for quantum electrodynamics

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The usual linear-response formalism in time-dependent density-functional theory (TDDFT) is applicable for fermionic systems only. Recently we have extended TDDFT to also include explicitly matter-photons interactions [1]. In the present work, we generalize the response formalism of standard TDDFT to treat also matter-photons interactions. To include the photon degrees of freedom, we extend the usual Dyson-type equation for the response function to a two-component equation, which takes the response of the electron density and the response of the photon energy density into account.
As a model system we consider lattice quantum electrodynamics (QED) in the linear regime. We calculate the exact Fock space dynamics of our coupled electron-photon system exposed to external laser fields. Using the Lanczos algorithm, we analyze the exact density change of the electrons and the change in energy density of the photons in real-time and compare with the linear-response solution provided by the generalized Dyson-type equation of TDDFT for QED.

[1] M. Ruggenthaler et.al., Phys. Rev. A **90**, 012508 (2014).

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