Energy-dependent perturbation theory for combined many-body and QED calculations

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Highly charged ions are suitable objects for testing QED at very strong fields, and with improved accelerators, such as the new FAIR facility, new challenging possibilities will appear. Then it is important that also theoretical methods are being developed to match the improved experimental accuracy.

Relativistic many-body calculations are usually based upon the projected Dirac-Coulomb (DC) or Dirac-Coulomb-Breit (DCB) Hamiltonians, the latter known as the no-virtual-pair approximation (NVPA), which includes all effects to order α^2 H(artrees). Effects beyond that order are referred to as QED effects and include virtual electron-positron pairs, retardation of the Breit interaction, as well as radiative effects. With the standard many-body techniques QED corrections can be included only in the form of first-order energy contributions [1]. Combined effects due to QED and electron correlation are expected, though, to be significant in the near future [2].

We have developed a procedure, where QED can be included directly into the wave function, which implies that these effects can be incorporated into the many-body procedure in a more systematic fashion [3]. The procedure is based upon the covariant-evolution-operator technique [4], recently developed for QED calculations.

Numerical calculations with the new technique have been performed for the ground state of some light and medium-heavy ions, where it has been found that combined many-body and QED effects beyond first order can be quite significant [5]. In the pipe line are applications to excited states, primarily fine-structure separations, where comparison can be made with recent accurate experimental results [6].

References

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