Numerical Implementation of the Relativistically Covariant Many-Body Perturbation Theory

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The standard procedure for relativistic many-body perturbation, MBPT, calculations is to use the no-virtual-pair approximation. Here, the negative-energy solutions of the Dirac equation are eliminated by projection operators. The procedure is not relativistically covariant, and effects of retardation, virtual-electron-positron-pair creation and radiative effects(self-energy, vacuum polarization and vertex correction)—the so-called QED effects— are left out.

The energy contribution of the QED effects can be evaluated by S-matrix formulation [1] or the two times Green's function method [2]. It has until now not been possible to include these effects into the wave function and merge them into a MBPT procedure. The covariant-evolution procedure, recently developed by the Göteborg group [3], can serve as the basis for such a merger.

The new procedure makes it, in principle, possible for the first time to evaluate QED effects together with correlation to high order, which is required in the treatment of light elements, such as light helium-like ions. There has recently also been discussions of the significance of higher order correlation between electrons in the medium-heavy elements [4]. The procedure is now being implemented, and it has been shown that the effect of electron correlation on first-order QED (retardation and virtual pairs) for He-like neon dominates heavily over second-order QED effects.

The only true covariant procedure for bound-state calculations that has been available so far is the Bethe-Salpeter equation (BSE). It has been demonstrated that our new procedure, carried to infinite order, leads for two-particle systems to BSE, demonstrating its relativistic covariance [5]. The procedure can therefore, in principle, be regarded as a Rayleigh-Schrdinger-based perturbation expansion of the Bethe-Salpeter equation, applicable to many-body systems, also in the multi-reference (quasi-degenerate) case.

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