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COMMENT ON THE SPACE TRANSLATION METHOD AS USED IN LASER-ASSISTED COLLISION PROBLEMS

G. Ferrante and C. Leone

Istituto di Fisica dell'Università, Via Archirafi 38, 90123 Palermo, Italy

*Istituto di Fisica della Facoltà di Ingegneria, Parco d'Orléans, 90128, Italy

The Space Translation Method (STM) was introduced in atomic physics in recent years by Henneberger to deal satisfactorily with the problem of the interaction of intense light fields with atoms and molecules, for which conventional perturbation theory is inadequate. Essentially the method consists of a time-dependent unitary transformation to an accelerated frame of reference, which was already known in quantum electrodynamics. Considering hydrogen atoms as an example, the effect of this transformation is to remove from the appropriate Schroedinger equation the (e/mc)^2 A(t) interaction between the e.m. field and the atomic electron, and to change the static electron-nucleus interaction V(r) into a time-dependent, displaced potential V(r + \xi(t)) with

\[ \xi(t) = - \int_0^t (e/mc)^2 A(t') dt' \]

being the classical displacement of a free electron from its center of oscillation in a radiation field.

The displaced potential may be separated into a static and a time-dependent part

\[ V(r + \xi(t)) = V_0 (r') + V_1 (r, t), \]

both being dependent on the laser field parameters.

As the unitarily transformed equations can not be solved exactly, the Henneberger's original proposal was to determine numerically approximate eigenstates and eigenvalues of the "dressed" Hamiltonian

\[ H_0 = -\frac{\hbar^2}{2m} \nabla^2 + V_0 (r'), \]

and then proceed with a conventional time-dependent perturbation theory treatment to perturb with V_1 (r, t) the dressed eigenstates of H_0.

The STM is used to study, among others, laser modifications of the spectra of isolated atoms, multiphoton ionization, laser-assisted particle-atom collisions and laser-assisted X-ray photoeffect. So far, however, none has fully and rigorously carried out the Henneberger's original proposal. Instead, several incomplete or simplified treatments are available, which not rarely produ-

+ Partially supported by GNSM-CNR and CRRNSM
ce ambiguous and puzzling results, in disagreement with those of more conventional treatments. This is particularly true in laser-assisted collision processes, where, sometimes, the STM fails to predict multiphoton processes, or effects due to free particle-field interaction. Some of the observed discrepancies due to the use of STM have been discussed and clarified by Lambropoulos et al., Ehlotzky and Ferrante et al. This Comment, instead, is concerned with the use of STM in laser-assisted collision problems. Reminding fundamental properties of the unitary transformations, it can be shown that if the unitary transformations, which are the essence of the STM, are performed properly, the STM gives essentially the same results as the more conventional treatments. The basic idea of this Comment is that any simplification of unitarily transformed operators adopted for solving the equations amounts to change the unitary operators, accomplishing the transformation. Accordingly, one must look for approximate new unitary transformations which when performed on the original equations yield the simplified transformed equations and/or operators. If this procedure is consistently carried out on all the operators and wavefunctions of the collision problems, disagreement generally disappears. Detailed analysis concerning inelastic laser-assisted electron-hydrogen collisions shows that any manipulation of the transformed atomic electron-nucleus interaction $V(\bar{r} + \bar{q}(t))$ requires significant changes into the wavefunctions and the interaction operators entering the S-matrix element, if one wants to ensure the necessary equivalence with the untransformed equations.

References