QED Effects in Excited States of Helium-Like Ions

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Abstract

The interest in the excited states of helium-like ions has increased in recent years mainly due to enhanced experimental accuracy, but also due to theoretical progress in describing these systems. Using bound-state QED, the electron correlation can presently be taken into account at the two-photon level to all orders in $Z\alpha$.

In this thesis a calculation of the non-radiative two-photon QED effects for the excited 1s2s ^1S and ^3S states in helium-like ions is presented. In this calculation the S-matrix approach of bound-state QED is used. A comparison is made between the calculated values and other theoretical values.

A major problem in bound-state QED based on the S-matrix is the treatment of the quasi-degenerate levels of the fine-structure in helium-like ions. This thesis presents an approach of treating these levels within the framework of bound-state QED, using the method of an extended model space together with an effective Hamiltonian. A covariant evolution operator is constructed which is found to be a generalization of the S-matrix. Explicit expressions to be used in calculations for all two-photon effects, including the self energy and vacuum polarization, are derived using the covariant evolution operator approach.

Numerical calculations of the non-radiative one- and two-photon exchange effects for all 1s2p ^1P and ^3P states in helium-like ions have been performed using this new approach. We compare with accurate experimental data and find very good agreement.

Keywords: helium-like, fine-structure, bound-state QED, S-matrix, extended model space, effective Hamiltonian, covariant evolution operator, two-photon exchange