Unified quantum theory on atomic multielectron processes: direct multiple ionization by an Auger decay, an electron or photon impact

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Synopsis An unified and practical quantum theory has been developed to investigate the atomic multielectron processes, taking the direct ionization by an Auger decay, an electron or a photon impact as examples. The new aprproach is based on the ansatz of the interference between a large number of quantum pathways is smeared out due to the continuous variations of phases in the transition.

Multielectron processes occurs widely in atoms, molecules, clusters, and even condensed matters when they are interacting with energetic particles or ultraintense laser fields. In most cases, direct multielectron processes are the most involved among the general multiple electron processes and are the most difficult to understand. An unified accurate and practical quantum theory is proposed on the direct atomic multielectron processes including the multiple Auger decay and multiple ionization by impact of an energetic electron or photon based on the atomic collision theory described by a fully correlated many-body Green's function. Such a practical treatment is made possible by fully taking advantage of the different coherence features of particles (matter waves) in the initial and final states. We first explain how the coherence characteristics of the ejected continuum electrons is largely destructed by taking the electron impact direct double ionization process as an example, which is different from the single ionization processes where the complete interference is maintained. The detailed expressions are extracted for investigation of the energy correlations among the continuum electrons and energy resolved differential and integral cross sections according to the separation of knock-out and shake-off mechanisms for the electron impact direct double ionization, direct double [1,2] and triple Auger decay, and double and triple photoionization processes. Extension to the higher-order direct multielectron processes than triple ones should be straight forward by adding the contributions of following knock-out and shake-off processes. As examples, the approach is applied to investigate the electron impact double ionization processes of C^+, N^+, and O^+, the direct double and triple Auger decay of the K-shell excited states of C^+ $1s2s^22p^2$ 2D and ^2P [3], and the double and triple photoionization of lithium. Comparisons with the available experimental results show that our proposed theoretical formalism is accurate and effective in treating the atomic multielectron processes.

Results for the simultaneous multiple ionization of atoms caused by an electron and photon impact or Auger ejection are just examples of the usability of this ansatz.The conclusion is independent on the specific process. Multi-lectron (particle) correlations (or entanglements) are the key issue to understand the many-body interactions in atoms, molecules, clusters, the Bose-Einstein condensation, and more general quantum many-body systems. The general ansatz we proposed may give a serious limitation on the possible application of multi-particle entanglements (or correlations) in, for an example, quantum information.

References

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