Two-photon recombination in the presence of cascade processes

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Abstract

The work is devoted to the study of two-photon hydrogen recombination in the presence of cascade processes. Within the framework of QED theory and the S-matrix approach, an analytical derivation and a numerical calculation of the radiative corrections to the one-photon recombination cross-section are given. It is shown that the imaginary part of the one-loop bound electron self-energy operator averaged on the wave functions of a continuous spectrum leads to a well-known expression for the cross-section of one-photon recombination. Within this approach, we show that the leading order correction to the free-bound one-photon process can be identified in a similar way by studying the imaginary part of the two-loop self-energy. The results of this study could have significant implications for the theoretical understanding of hydrogen recombination kinetics, and may contribute to ongoing astrophysical research on the primordial hydrogen plasma in the early universe.

Key words: Theoretical Physics, Atomic Physics, Astrophysics

Recently, in the previous work of our scientific group, it was shown that in the presence of cascade processes, there is a fundamental difference between the two-photon level width of the excited atomic state and the corresponding two-photon transition rate [1, 2]. In particular, in [1], using the example of bound $ns/nd - 1s(n \geq 3)$ transitions in hydrogen, it was shown that the two-photon widths of the excited levels, evaluated as the imaginary part of the two-loop bound electron self-energy correction to the energy level, differ from the corresponding two-photon decay rates when one-photon cascade processes are taken into account. The obtained results can be interpreted as radiative corrections to the one-photon width.

In the present work, we continue our study by focusing on free-bound transitions and considering two-photon recombination in a hydrogen atom. Within the framework

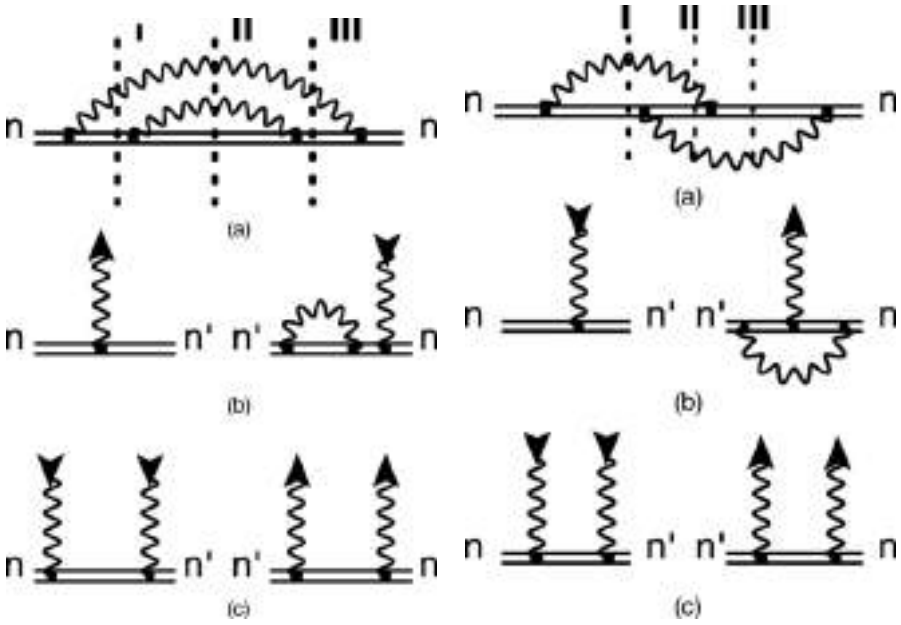

Figure 1: Feynman graphs of irreducible contributions of the two-loop self-energy of a bound electron. The three cuts I, II, II in (a) correspond to the products of amplitudes as depicted for the cut I in (b) and for the cut II in (c). A picture for the cut III is similar to that in (b). These pictures demonstrate that only the cut II corresponds to the contribution to the two-photon width [1, 2].

of QED theory and the S-matrix formalism, an analytical derivation and numerical results of the radiative corrections to the one-photon recombination cross-section is given. Following the work of [4], we consider the imaginary part of the two-loop self-energy operator averaged over the wave functions of the continuous spectrum, see Fig. 1. It is shown that with this approach the resulting expression contains no resonance terms and represents a radiative correction to the one-photon recombination cross section.

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