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Two-loop self-energy corrections to the bound-electron g-factor: Status of M-term calculations

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The theoretical uncertainty of the bound-electron g-factor in heavy hydrogen-like ions is dominated by uncalculated QED Feynman diagrams with two self-energy loops. Precision calculations of these diagrams in which the interaction between electron and nucleus is treated exactly are needed to improve the theoretical accuracy of the bound-electron g-factor in the high-Z regime. Results of such calculations are highly relevant for ongoing and future experiments with high-Z ions at the ALPHATRAP and HITRAP facilities, as well as for an independent determination of fundamental constants such as the electron mass m_e and the fine structure constant α from the bound-electron g-factor [1,2]. Furthermore, comparisons of theory and experiment for heavy ions can serve as a probe for physics beyond the Standard Model after an improvement of the theoretical accuracy through the completion of two-loop calculations [3].
Due to the presence of ultraviolet divergences, two-loop self-energy Feynman diagrams need to be split into the loop-after-loop (LAL) contribution and the so-called F-, M- and P-terms which require different analytical and numerical techniques. The F-term corresponds to the ultraviolet divergent part of the nested and overlapping loop diagrams with free electron propagators inside the self-energy loops. The M-term corresponds to the ultraviolet finite part of nested and overlapping loop diagrams in which the Coulomb interaction in intermediate states is taken into account exactly. In our previous work, we have obtained full results for LAL and the F-term [4]. In this work, we present our results for the M-term contribution. P-term contributions correspond to diagrams which contain both bound-electron propagators inside the self-energy loops as well as an ultraviolet subdiagram and will be considered in a future work.

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