Coulomb corrections to the two-loop vacuum polarization potential and their contribution to the Lamb shift of hydrogenlike ions

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The QED vacuum polarization potential corrections of orders $\alpha^2(Z\alpha)^3$ and $\alpha^2(Z\alpha)^5$ around a point charge were calculated. The values for arbitrary transferred momentum were obtained in tabular form. The results of order $\alpha^2(Z\alpha)^3$ agree with the previously calculated value [1] at zero momentum; the ones of order $\alpha^2(Z\alpha)^5$ were computed for the first time.

The obtained results improve the accuracy of the 2-loop vacuum polarization Lamb shift corrections significantly, especially in heavy ions and exotic atoms.

The potential calculation is based on the free QED Feynman diagrams, where the Coulomb potential lines are treated as propagator lines. These diagrams may have up to 6 loops in terms of free QED, and the development of special methods is required to make the computation feasible. A method similar to the one used for calculating the 5-loop free electron g-2 [2] was employed. The following topics are the subject of consideration: the principle of the reduction to finite integrals, renormalization and elimination of intermediate infrared and ultraviolet divergences, Monte Carlo integration, realization on GPUs.

References

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