The 413 nm tune-out wavelength for $2\,^3S_1$ state of helium as test of QED

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The tune-out wavelength is the wavelength at which the dynamic dipole polarizability vanishes. The 413 nm tune-out wavelength of the $2\,^3S_1$ state of helium is proposed as a non-energy test of quantum electrodynamic (QED) [1], which sparks great interest in high-precise measurement [2] and high-accuracy calculations of the tune-out wavelength of helium [3, 4]. So far, there exists 19 ppm discrepancy between the trapped-atom dynamics measurement of 413.0938(9stat)(20syst) nm [2] and the relativistic configuration-interaction (RCI) calculation of 413.0859(4) nm [3]. In present work we performed larger-scale RCI calculation based on the Dirac-Coulomb-Breit (DCB) equation with the mass shift operators included directly in the Hamiltonian. The advantage of this developed RCI method is that the finite nuclear mass and relativistic nuclear recoil corrections on the tune-out wavelength are taken into account self-consistently in DCB framework. The QED correction on the tune-out wavelength is also estimated. Our result of tune-out wavelength is 413.090 13(5) nm with an uncertainty of 0.12 ppm, which is more accurate than the experimental value from Ref. [2]. This work will motivate a future experimental campaign to seriously test QED at higher level of accuracy.

Contributions	λ_t (nm)
RCI	413.085 87(3)
α^3 QED without $\partial_\varepsilon^2 \ln k_0$	0.004 145 6(2)
α^3 QED from $\partial_\varepsilon^2 \ln k_0$	0.000 04(1)
α^4 radiative term	0.000 071 4(2)
Total	413.090 13(5)
Experiment [2]	413.093 8(9_{stat})(20_{sys})

Table 1: Comparison of the 413 nm tune-out wavelength for the $2\,^3S_1(M_J = \pm 1)$ state of ^{4}He.

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