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Disentangling relativistic non-dipole effects in strong field atomic ionisation in non-relativistic regime

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Synopsis
Quantum mechanical description of the relativistic non-dipole effects is of fundamental interest in strong-field physics community, as they may have direct implications on the processes relying on re-collision dynamics. Here, we present a detailed experimental and theoretical study on the relativistic non-dipole effects in strong-field ionisation at moderate intensities. We compare our precise measurements with a truly ab-initio fully relativistic 3D model based on the time-dependent Dirac equation and demonstrate an excellent agreement between experimental results and theoretical predictions.

Relativistic non-dipole effects are known to have subtle effects on the re-collision electron dynamics in strong field ionisation and very important to study for a deeper insight into phenomena such as harmonic generation, atomic stabilisation, photo-electron holography etc [1]. We explore correlated electron dynamics obtained as a result of strong field ionisation of argon to study relativistic non-dipole effects in the non-relativistic intensity regime (10\(^{14}\) - 10\(^{15}\) W/cm\(^2\)) using near-infrared linearly-polarised few-cycle laser pulses. These effects leave their signatures in the high-resolution, three-dimensional photo-electron momentum distributions recorded by a reaction microscope. In particular, they reveal themselves differently in the transverse electron momentum distribution (TEMD) as a function of laser intensity. We observe increasing counter-intuitive shifts of the peak of the TEMD with increasing laser intensity.

Furthermore, we support our experimental results by a truly ab-initio fully relativistic 3D model based on numerical solution of 3D-TDDE to investigate the relativistic non-dipole effects, which was always considered a formidable task so far. Owing to the importance of addressing relativistic non-dipole effects in strong field ionisation processes [2], such a relativistic development of theory is indispensable for the description of the ionization phenomena occurring for the currently available laser intensities of the order of 10\(^{18}\) W/cm\(^2\) and beyond. Our approach based on the Dirac equation incorporates relativistic effects, such as the non-dipole effects, effects of the relativistic kinematics and spin-orbit interactions in the most natural way compared to numerous other theoretical models developed until now.

Furthermore, for a better understanding of the underlying physics behind these non-dipole effects, we compared our existing results with the simulations done for a Model Ar atom with Yukawa potential to disentangle the combined effects of Coulomb potential and radiation pressure on the peak shift.

References

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