Ionization in intense laser fields beyond the electric dipole approximation

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Synopsis
I will review our work for which the dipole approximation is not valid but a fully relativistic description is not required and would like to dedicate this talk to Howard Reiss who died last year (25. Aug. 2022).

The electric dipole approximation is widely used in atomic, molecular and optical physics and is typically related to a regime for which the wavelength is much larger than the atomic structure. However, studies have shown that in strong laser fields another regime exists where the dipole approximation breaks down. Figure 1 shows the green area (the dipole oasis), for which the dipole approximation and the tunneling ionization theory is valid, according to Howard Reiss [1].

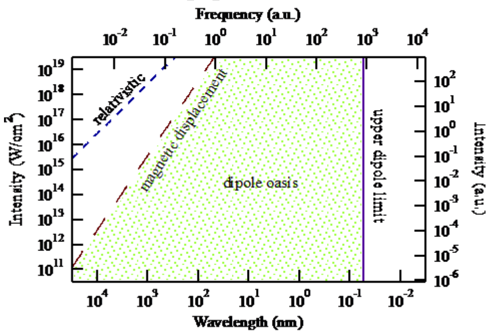

Figure 1. Illustration of the validity range of the dipole approximation, as published in our review article 2021 [2] and according to Reiss [1].

Many experiments have confirmed that the dipole approximation breaks down when moving to either high intensities or to longer wavelengths as shown in Fig. 1. During the ionization process in intense laser fields and at long wavelengths the photoelectrons can reach higher velocities such that the magnetic field component of the laser field becomes significant. The ionization dynamics and the final momentum of the electron is therefore modified by the entire Lorentz force. In contrast the magnetic field interaction is neglected in the dipole approximation.

This talk will review how the breakdown of the dipole approximation is affecting strong laser field interactions and how attosecond time resolution can provide a better understanding.

In the regime of strong field ionization for example the maximum of the photoelectron distribution is shifted opposite to the laser beam propagation direction, which is counter-intuitive within the framework of the radiation pressure [3]. More detailed studies as a function of ellipticities [4-5] also shows how the attoclock measurement [6-7] is affected. We also addressed the question how the transfer of linear momentum of the involved photons are transferred to the photoelectron and used the attoclock technique to resolve a time delay between the minimum of the linear momentum transfer and the maximum of the ionization rate [7].

With further developments in ultrafast lasers at high intensities and long wavelength such experiments with attosecond time resolution will continue to reveal a better understanding of light matter interactions.

References

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