# Analytical non-perturbative model for atomic RABBITT-like experiments

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**Synopsis** We study theoretically the single photon ionization of atomic targets by an attosecond pulse train assisted by an infrared laser field. We employ a non-pertubative model that under certain approximations gives closed form expressions for the observables of the reaction. Interestingly, this analytical expressions allow us to interpret the angular distributions of photoelectrons as two-center interferences where the separation between the virtual emitters is governed by the infrared laser field.

Among the different techniques developed since 2001, when the first attosecond pulses were obtained [1, 2], the so called reconstruction of attosecond bursts by interferences of two-photon transitions (RABBITT) plays a central role.

In the usual RABBITT scheme, atomic or molecular targets are exposed to the simultaneous action of an attosecond pulse train and a near infrared laser field (NIR) of low intensity. As the production of attosecond pulse trains is routinely achieved by means of a high-order harmonic generation process by focusing an intense ultrashort near infrared laser field pulse into a noble gas atom chamber [3], the spectrum of the resulting radiation is given by a comb of odd harmonics of the laser that generates it. Therefore, the photoelectron spectrum corresponding to the usual RABBITT technique contains dressed harmonic lines populated by the absorption of a given harmonic in the attosecond pulse train, and sideband lines associated to the further exchange of one photon from the low-intensity NIR. As a consequence of the interference between the two quantum paths that may populate the sidebands, their magnitude oscillates when the delay between the assistant laser field and the attosecond pulse train is modified. On the other hand, the magnitude for dressed harmonic lines remains unchanged when the delay is modified, as they are populated by a single contribution.

Due to the low NIR intensity usually employed in these experiments, the number of NIR photons absorbed or emitted by the photoelectrons in the continuum can be safely constrained to one, and thus the properties of the photoelectron spectrum are well reproduced by a second-order perturbation theory [1]. On the contrary, the intermediate NIR intensity regime, where more than one NIR photon may be exchanged, requires a theoretical treatment beyond the second-order perturbation. Moreover, recent experimental and theoretical studies showed that the global shape of the angular distributions (ADs) in the principal bands changes significantly for different delays, as opposed to the sideband lines which are almost insensitive to the delay after normalization [4].

As we showed recently [5, 6] by means of an extension of the Separable Coulomb-Volkov model, it is possible to obtain analytical expressions describing the photoelectron angular distributions in RABBITT-like experiments, where the interaction of the photoelectron and the NIR is treated to all orders. Interestingly, our model indicates that the angular distributions for atomic targets assume the same functional form corresponding to the monochromatic photoionization of molecular targets, as given by Cohen and Fano [7, 8], with a separation vector between virtual emitters governed by the infrared laser field.

In this contribution, we study the angular distributions of photoelectrons in RABBITT-like experiments for different NIR intensities. We compare the results of our model with recent experimental results and discuss the possible mechanisms for the control of photoelectron emission.

## References

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