Light Matter Interaction with Few-Cycle Pulses: How is it different from the Many-Cycle Pulse Interaction?

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The smoothly varying envelop approximation that forms the basis of the Rotating Wave Approximation (RWA) in many-cycle pulses is not applicable in few-cycle pulse limit. This complicates the study and interpretation of light matter interactions at the few-cycle limit. On the other hand, few-cycle laser pulses at near-IR wavelengths have temporal durations of the order of a few femtoseconds. So, any generic ground to excited state transition in a molecule under the influence of such pulses would be treated as an ideal and non-relaxing since typical molecular relaxation processes occur over much longer timescales [1]. We show the utility of this simplification. We make a comparative study of few-cycle pulse interactions and the more traditional many-cycle pulse interactions to emphasize the novel benefits of the few-cycle pulse interaction process. We present a model study of the interaction of few-cycle pulses with ideal two-level systems. Our results show that despite the overwhelming importance of the oscillatory nature of the few cycle pulse, the signature of the pulse envelope still persists in the interactions. To prove our conjecture, we used various envelope functions to show their impact on the population cycling between the two-levels [2]. The interaction between a few-cycle laser pulse and an ideal two-level system, without relaxation, was simulated without invoking any approximations [3]. The simulations were performed using Euler Forward Time Integration method. The time step was fixed to be much less than the duration of a single oscillation. We worked with Gaussian, Cosine squared and Hyperbolic Secant pulse profiles with varying widths, and consequently varied the number of cycles per pulse. Rabi flopping defines the quintessential characteristic of later-matter interaction for many-cycle pulses: The point of deviation from the atypical Rabi flopping as a function of number of cycles sustained in the pulse was used as the measure of the dominance of the pulse cycling effect over the envelope profile effect. Specifically, we demonstrate the construction of a quantifiable measure, which shows that the envelop profile characteristics play an important role in matter-radiation interaction even for few-cycle pulses. We show that RWA breaks down even in the many cycle pulse domain after certain area. We also show how the relative phase within the pulse can act as a pulse shaping control knob in the few cycle limit.

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