When Ultracold Meets Ultrafast: Attosecond Science in Slow Motion

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The full *ab initio* treatment of atoms and, especially, of molecules exposed to ultrashort intense laser fields remains a paramount challenge. In fact, solutions of the time-dependent Schrödinger equation for atoms or molecules in intense laser fields are presently basically restricted to two-electron systems like helium atoms or hydrogen molecules. It is evident that the complete exact theoretical treatment of atoms or molecules with more than a very small number of electrons and nuclei will remain an unsolvable task for any classical computer, since the corresponding Hilbert space increases exponentially and the interaction with an intense laser field quickly spreads the electronic wave functions over a very large volume both in position and momentum space. In such a situation, a quantum simulator may provide an alternative approach to the problem. Such a quantum simulator for strong-field physics, based on trapped ultracold neutral atoms is discussed in this talk. It allows for the exploration of the features of strong field-physics on a much slower time scale. In fact, the sub-femtosecond processes known from the famous three-step model that explained, e.g., high-harmonic generation and are the basis for generating attosecond light pulses are slowed down by 12 orders of magnitude, resulting in processes on the millisecond time scale. This should provide a detailed glance into tunneling processes. More importantly, the extreme flexibility of the quantum-simulator system allows for systematic studies of the influence of the trapping potential (including multi-well structures simulating molecular potentials) and, especially, of the many-particle interactions on the strong-field response of atomic and molecular systems. In turn, interesting new perspectives may open for the physics of ultracold quantum gases, if, e.g., the time-resolved imaging techniques developed in strong-field physics are adopted to periodically driven trapped ultracold quantum gases.