TAILORING ATOMIC WAVEFUNCTIONS WITH DESIGNER PULSES

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Manipulation and control of the electronic states of atoms provides an exciting new area of research in atomic physics with important potential applications. Such control can be achieved using "designer" electromagnetic pulses whose strengths are comparable to the Coulomb electric field and whose durations are of the order of the classical orbital period of the atom. Coherent control of the electron dynamics requires complete knowledge of the initial state as well as of the pulses whose shapes can be carefully tailored at will.

Recently, the generation of "half-cycle" electromagnetic pulses (HCPs) in the terahertz, gigahertz, and megahertz regime has been achieved. They are characterized by a strong unidirectional electrical field confined to a very short time interval. In collaboration with B. Dunning and coworkers at Rice University, we have demonstrated the possibility of controlling atomic wavefunctions using very high-n Rydberg atoms and "designer" pulses consisting of superpositions of HCPs which can be shaped at will.[2–5] We have found new possibilities in producing and probing coherent atomic wavepackets, and we have produced the first realization of the periodically kicked atom, a paradigmatic system of non-linear dynamics using a superposition of half-cycle pulses. Moreover, we have shown that these systems provide an ideal testing ground to probe the correspondence between the classical and quantum mechanical time-dependent dynamics of the electron in the atom.

We have recently reported theoretical and experimental evidence for the dynamical stabilization of Rydberg atoms subject to a train of unidirectional short pulses. The survival probability as a function of the pulse repetition frequency displays pronounced peaks that can be attributed to the existence of stable islands in the classical three-dimensional (3D) phase space. After several pulses, the wavefunction of the system adopts the shape of the classical stable islands. We are currently performing quantum calculations, solving the time-dependent Schrödinger equation, to analyze quantum stabilization phenomena in great detail. If quantum stabilization exists, it originates in the localization of a few Floquet states of the system. In the limit of large quantum numbers, the Husimi distributions of the dominant Floquet states leading to stabilization should be localized in phase space around the dominant classical stable islands. However, even for conditions such that classical dynamics is fully chaotic, another type of quantum localization can occur which has no classical analog: e.g. Anderson localization. We plan to investigate both types of localization phenomena.

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