Comment on "Physical Reality of Light-Induced Atomic States"

In a recent Letter [1], Wells, Simbotin, and Gavrila discuss the "physical reality of light-induced atomic states" (LIS), as opposed to "regular states." They claim that (1) "...the evolution of the LIS cannot be followed from a field-free limit," and (2) that they "show here, for the first time, that wave-packet evolution confirms the physical reality of the LIS."

A careful examination compels us to take issue with the above statements. The central point in [1] is the apparent "materialization" and possible "disappearance" of LIS as a function of the quiver amplitude α, at quasienergies defined by the field-free continuum threshold displaced by an integer multiple of the photon energy. We repeated the diagonalization of the Floquet eigenvalue problem represented in Figs. 1 and 2 of [1]. Our diagonalization is performed in a B-spline basis [2] using a combination of complex scaling, Floquet theory, and the Lanczos algorithm [3]. Our results are shown in Figs. 1(a) and 1(b), where we chose the Floquet zone to start at the ground and the second excited states of the model potential of [1], respectively. The figures clearly show that the field-free limit of what the authors of [1] call "LIS1" are the ground and the second excited state of the model potential. Of course, both states undergo avoided crossings with the continuum threshold shifted downwards from $E = 0$ by two or one photons, as clearly seen in Fig. 1. This, however, is a ubiquitous phenomenon, at least in the physics of microwave driven Rydberg states, which solve *precisely the same* eigenvalue problem (except for the smoothing of the Coulomb singularity in [1], which is irrelevant in the present context) [3]. Take, e.g., the hydrogen Rydberg state $n = 21$ driven by a microwave field of frequency $\omega = 10^{-4}$ a.u. (i.e., close to resonance with the transition to the state $n = 22$). Then, a little more than 11 photons are needed to ionize the atom, and the state emanating from the field-free state $n = 21$ at finite field amplitude will cross with the high lying Rydberg states converging to the continuum threshold displaced downwards by 11 photons (these states have principal quantum numbers above $n \simeq 120$). Any pulse envelope of the field driving the Rydberg state with a finite rise time can only resolve avoided crossings below a finite principal quantum number n_c, as the size of the crossings scales as $n^{-3/2}$ [4]. As a consequence of this coarse graining of the energy scale, all avoided crossings beyond n_c are *irrelevant* for the identification of the so-called LIS. Any finite time scale (necessarily involved in the measurement of a physical observable) therefore even defines an adiabatic field-free limit of what the authors of [1] call LIS. Hence, the LIS are nothing more than dynamically shifted states of the bare atom, and their "physical significance" is anything but "uncertain." Furthermore, contrary to statement (2) above, there is a vast amount of literature where the population of such Rydberg states shifted across photon-displaced continuum thresholds through diabatic passage from the field free limit has been discussed and demonstrated, even for real atoms (see Refs. [3,5,6], and references therein). In addition, it has been shown that such states can also be probed by Floquet spectroscopy [6].

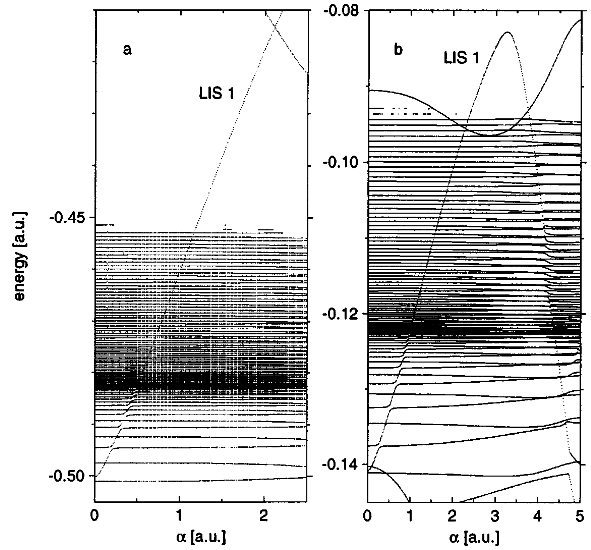

FIG. 1. Evolution of the Floquet spectrum of the model potential of [1], as a function of the quiver amplitude α. Driving frequency: $\omega = 0.24$ a.u. (a), $\omega = 0.12$ a.u. (b). The Floquet zone is chosen to start close to the field-free energy $W_0 = -0.5$ of the ground state and of the second excited state $W_2 = -0.141$ of the potential, respectively. One clearly observes that the LIS1 of [1] originate from W_0 and W_2, respectively. The quasienergies (above the displaced continuum threshold) which remain almost constant over the entire range of α represent continuum states in our discrete basis.

Since the raison d'être of [1] is the LIS and their special properties, we feel that our above remarks should be of considerable interest to a general readership.

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