Comment on "Nondispersing Bohr Wave Packets"

In a recent Letter [1], Maeda *et al.* report the creation of localized nondispersing "Bohr-like" wave packets moving in near-circular orbits with $l \sim n - 1$ and $m \sim -l$ starting from Li($72p$) states by using a resonant microwave field whose polarization is slowly changed from linear to circular. Their production was inferred from measurements of the time evolution of the x and y components of electron momentum, p_x and p_y, i.e., the components in the plane of the orbit, using half-cycle pulses. Here, we examine this protocol using classical trajectory Monte Carlo simulations. While the simulations are consistent with the experimental observations in [1], they question their interpretation pointing rather to creation of a state comprising a superposition of orbits with a broad distribution of orientations and relatively small angular momenta.

The applied fields used in the simulations [Fig. 1(a)] mirror those used experimentally. Detailed analysis of electron trajectories reveals that as the initial microwave field (polarized along the y axis) builds up, it drives an oscillation in the average y component of electron momentum, p_y, that is synchronized with the field resulting in periodic oscillations in $\langle p_y(t)\rangle$. Buildup of the orthogonally polarized microwave field similarly results in a periodic oscillation in $\langle p_x(t)\rangle$ which remains as the y-polarized field is turned off. Thus, as shown in Figs. 1(b)–1(d), the simulations reproduce the dynamical behavior reported in [1] for $\langle p_x(t)\rangle$ and $\langle p_y(t)\rangle$. Although the ensemble of resulting classical orbits display a variety of precessional behaviors as the driving fields are changed, simulations using different microwave turn on and turn off times (>10 ns) and $72p$ sublevels provide no evidence of creation of localized Bohr-like states. Rather, they suggest formation of a wave packet with a broad distribution of L_z peaked at $L_z \sim 0$ [see Fig. 1(e)], not $L_z \sim \pm(n-1) \sim \pm 70$ (a.u.) characteristic of a near-circular state. Indeed, $\langle L_z(t)\rangle$ remains close to zero [Fig. 1(a)] implying that the electrons follow elliptic orbits with many different orientations. Those on ellipses oriented predominantly along the $x(y)$ axis synchronize with the $x(y)$-polarized components of the driving fields. The population of low-L_z states can be further seen in Fig. 1(f): the electron probability density extends well beyond the radius of the Bohr orbit (n^2) and peaks near the origin ($x = y = 0$) due to the projection of the broad distribution of orbit orientations onto the xy plane. Analysis of the phase space density reveals almost no population near the stable point described in [2]. Indeed, the size of the time-dependent oscillations in survival probability seen in [1] are much smaller than those observed in [3] for a Bohr-like $n \sim 300$ wave packet.

The predictions of the classical simulations are supported by fully quantal time-dependent calculations and Floquet analysis undertaken at lower n. Quantum calculation of the Floquet energy spectrum as a function of the ellipticity of the microwave driving field shows that high-l states only couple weakly to p states, a finding consistent with the analysis of the microwave driven Rydberg atom in [4]. Thus, high-l states cannot be readily accessed from p states, resulting in creation of a distribution of lower l states.

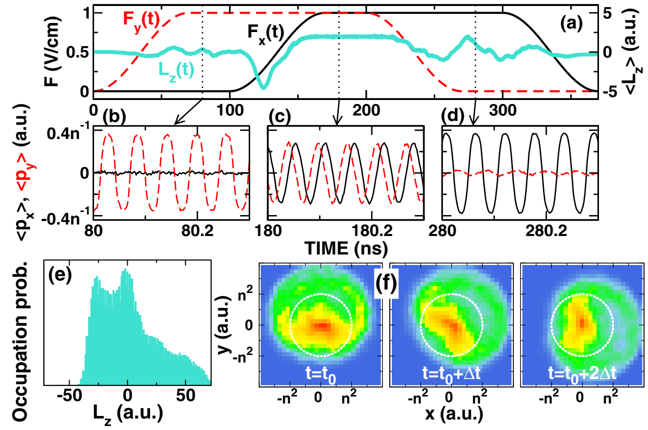

FIG. 1 (color online). (a) Amplitude of the 17.6 GHz microwave driving fields and time evolution of the average angular momentum $\langle L_z(t)\rangle$ of the wave packet. (b)–(d) Time evolution of the average momentum, $\langle p_x(t)\rangle$ solid line and $\langle p_y(t)\rangle$ dashed line, of the wave packet when the microwave polarization is (b) linear along the y axis, (c) circular, and (d) linear along the x axis. The initial state is a subset of a microcanonical ensemble corresponding to the $72p$ $m_y = 0$ Rydberg state. (An $m_x = 0$ state yields similar results.) (e) Distribution of L_z at $t = 180$ ns. (f) Electron probability density projected on the xy plane for $t_0 = 180$ ns, $\Delta t = 7$ ps. The white circle denotes a circular orbit of the Bohr atom with radius $\langle r\rangle = n^2$.

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