Wavefunction Microscopy: Simple Atoms under Magnification

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The wavefunction is the main entity used to describe microscopic properties of matter in quantum mechanics. However, in general, its direct measurement is still an inaccessible quest. Observing directly, in real-space, the square modulus of the wavefunction (probability density) is from this point of view the first step to a direct insight into this elusive object.

In order to observe directly the square modulus of an atomic wavefunction, it must first be expanded to a macroscopic scale. Photoionization in the presence of an electric field provides such a magnification, allowing the wavefunction to propagate at large distance, and ensuring at the same time the boundedness along one coordinate. Therefore, simply measuring the spatial distribution of the electron flux using a high-resolution velocity map imaging spectrometer may allow, under appropriate conditions, to observe the square modulus of the electron wavefunction as suggested in [1]. In addition, an atom in an external electric field possesses quasi-discrete Stark resonances in the continuum. Therefore, not only the continuum wavefunction can be observed, but the wavefunction of a quasi-bound state bearing intrinsic properties of the atom may be visualized.

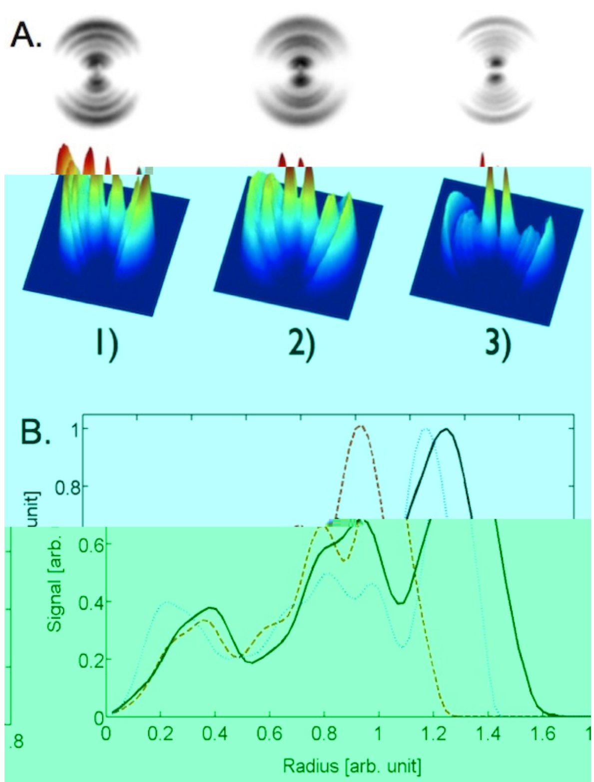

Figure 1: *(A) 2D and 3D representation of experimental images in one-photon ionization of lithium. F=1000 V/cm: (1) below, (2) on, and (3) above the (n1=6, m=1) resonance. (B° radial distribution: the image is larger on-resonance (black curve) owing to tunnel ionization.*

By exciting simple atoms like lithium [2] or hydrogen [3] in the presence of an electric field, we obtained the first experimental wavefunction microscopy images where signatures of quasi-bound states were evident. In this communication, we report such experiments where the nodal structure of the atomic state is directly observed, exhibiting a clear contrast between continuum and resonance features.

References

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