From One to Many Photons: Connecting field ionization to photoionization via GHz microwave ionization of Rydberg atoms

Here we present experimental results connecting field ionization to photoionization in Li Rydberg atoms obtained with 17- and 36-GHz microwave fields. At a low principal quantum number \( n \), where the microwave frequency \( \omega \) is much lower than the classical, or Kepler frequency, \( \omega_K=1/n^3 \), microwave ionization occurs by field ionization, at \( E=1/9n^4 \). When the microwave frequency exceeds the Kepler frequency, \( \omega>1/n^3 \), the field required for ionization is independent of \( n \) and given by \( E=2.4\omega^{5/3} \), in agreement with dynamic localization models, which cross over to a Fermi’s Golden Rule approach at the photoionization limit. A surprising aspect of our results is that when \( \omega\approx1/2n^2 \), the one- and multiphoton ionization rates are similar, and even at the lowest microwave powers, all are 10 times lower than the perturbation theory rate calculated for single-photon ionization. Further, we show that when the Rydberg atoms are excited in the presence of the microwave field, the probability of an atom’s being bound at the end of the microwave pulse passes smoothly across the limit. This microwave stimulated recombination to bound Rydberg states can be well described by a simple classical model. More generally, these results suggest that the problem of a Rydberg atom coupled to a high-frequency microwave field is similar to the problem of interchannel internal coupling in multilimit atoms, a problem well described by quantum defect theory.