Autoionization of very-high-n strontium Rydberg atoms

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Synopsis The autoionization of high n, n~280-430, strontium Rydberg states through excitation of the 5s $^2S_{1/2}\rightarrow$ 5p $^2P_{1/2}$ transition in the core ion is investigated. The autoionization rates decrease rapidly as L is increased paving the way for production of long-lived two-electron-excited planetary atoms.

The ability to create localized wave packets in Rydberg atoms whose behavior mimics that of a classical particle suggests the possible engineering of atoms that contain two excited electrons, each moving along quasi-classical orbits. While such atoms, termed planetary atoms, have been the subject of much theoretical interest,[1] their practical realization is a challenge because interactions between the excited electrons can lead to rapid autoionization. In the present work we explore autoionization using very-high n strontium Rydberg atoms, and the techniques that can be used to control it.

Strontium atoms in a collimated beam are excited to selected n^1P_1 or n^1F_3 states and autoionization is induced by exciting the 5s $^2S_{1/2}\rightarrow$5p $^2P_{1/2}$ transition in the core ion using a 100ns-long pulse of 422 nm laser radiation. (Use of a short pulse minimizes population of the long-lived 4d $^2D_{3/2}$ state which can also induce autoionization) The number of surviving Rydberg atoms is determined by field ionization.

Measurements with both nP and nF states in which the frequency of the 422 nm laser is scanned reveal broad autoionization features whose widths decrease with increasing n and, in the limit of very high n, approach that of the transition in the Sr^+ core ion.

The effect of increasing the angular momentum, L, of the excited Rydberg electron is examined either by initially exciting selected extreme Stark states in a dc electric field or by sudden application of a "pump field" to n^1P_1 atoms which creates a Stark wavepacket that undergoes Stark precession resulting in periodic changes in $|L|$. [2] Even modest increases in L are found to result in a dramatic decrease in the autoionization loss. This is illustrated in Fig. 1 which shows the fraction of n=320 $^1P_1$ atoms that survive autoionization versus the duration of the pump pulse.

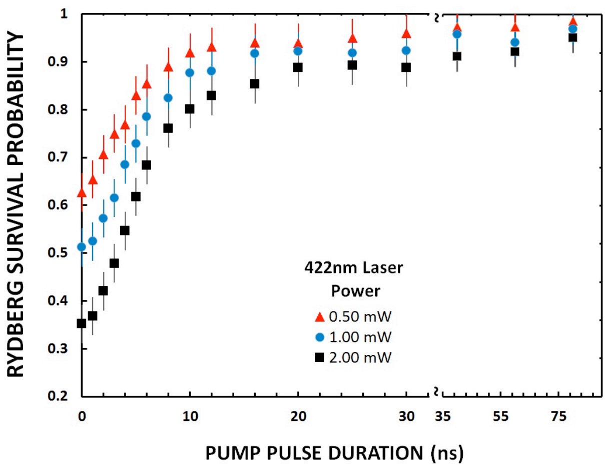

Figure 1. Rydberg atom survival probability versus pump pulse duration.

Pulse durations of ~10-15 ns are sufficient to populate states with $|L|$~20-30.

The present work indicates that by placing one electron in an outer localized very-high-n, high-ℓ, ℓ~n, near-circular Bohr-like orbit, it should be possible, with further excitation of the inner electron, to produce long-lived two-electron-excited planetary atoms.

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References

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