Millimeter-wave precision spectroscopy of d-d transitions in potassium Rydberg states*

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Abstract

We measure two-photon millimeter-wave transitions between nd_j and $(\mathrm{n+1})\mathrm{d}_j$ Rydberg states for $30 \leq \mathrm{n} \leq 35$ in ^{39}K to an accuracy of 5×10^{-8} to determine high-n d-state quantum defects and absolute energy levels. ^{39}K atoms are magneto-optically trapped and cooled to 2-3 mK, and excited from ground state $4\mathrm{s}_{1/2}$ to $\mathrm{nd}_{3/2}$ or $\mathrm{nd}_{5/2}$ by frequency-stabilized 405 nm and 980 nm external-cavity diode lasers in succession. The magnetic-field insensitive $\mathrm{nd}_j \rightarrow (\mathrm{n+1})\mathrm{d}_j$ $\Delta\mathrm{m} = 0$ transitions are driven by a 16 μs-long pulse of mm-waves before the atoms are selectively ionized for detection. The (n+1)d population is measured as a function of mm-wave frequency. Static electric fields in the MOT are nulled in three dimensions to eliminate DC Stark shifts. The two-photon transitions exhibit small but measurable AC Stark shifts in the resonance frequencies. We determine the field-free intervals both by extrapolating a sequence of measurements made as a function of mm-wave power to zero and directly without extrapolation by applying Ramsey's separated oscillating fields method, scanning the delay between two short, intense, pulses and measuring the beat frequency. Our results give quantum defects for the high-n states that are an order of magnitude more accurate than earlier measurements of these quantities.

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