Precision Measurement of the 5s $^2S_{1/2} \rightarrow$ 5p $^2P_j \rightarrow$ 5d$^2D_{3/2}$ Two-photon, Two-color Polarization Spectrum in Atomic ^{87}Rb

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A number of sophisticated techniques have been applied to precise measurements of the strength of resonance transitions in the heavier alkali atoms. These include refined lifetime measurements in atomic beams, photoassociative spectroscopy of cold atoms confined to atomic traps, and direct measurements of the natural width of an atomic transition. We have made a precise study of the 5s $^2S_{1/2} \rightarrow$ 5p $^2P_j \rightarrow$ 5d$^2D_{3/2}$ transition in atomic ^{87}Rb. Measurements of the nonresonant two-photon, two-color linear depolarization spectrum shows remarkable polarization-dependent interference structure. Using this novel approach, it was possible to extract the ratio of the transition matrix elements for the two contributing pathways. Spectral analysis yields a value of 1.067(7) for the ratio of 5s(j=1/2) - 5d(j'=5/2, 3/2) matrix elements, departing from the nonrelativistic limit where R = 1.

In the experiment, two independently tunable lasers having frequencies ω_1 and ω_2 are adjusted to satisfy the two photon resonance condition $\omega_1 + \omega_2 = \omega_0$, where ω_0 is the two-photon resonance frequency of the 5s $^2S_{1/2} \rightarrow$ np $^2P_j \rightarrow$ 5d$^2D_{3/2}$ transition. Averaged over the hyperfine structure, ω_0 = 25700.56 cm-1 . Detuning is defined as $\Delta_1 = \omega_1 - \omega_{3/2}$, where $\omega_{3/2}$ = 12816.58 cm-1 is the resonance frequency of the 5s $^2S_{1/2} \rightarrow$ 5p $^2P_{3/2}$ transition. Detection of atoms promoted to the 5d$^2D_{3/2}$ level is achieved by monitoring the 6p $^2P_j \rightarrow$ 5s $^2S_{1/2}$ cascade fluorescence around 420 nm. The two-photon laser polarimeter employed two tunable single-mode diode lasers. Laser 1 was a temperature-tuned diode laser delivering $\sim$ 40 mW in an average bandwidth $\sim$ 50 MHz; the frequency ω_1 was monitored by a precision wavemeter. Laser 2 was an external-cavity tuned diode laser providing 6 - 9 mW of power in a bandwidth typically $<$ 10 MHz. The polarization direction of laser 2 was controlled by a liquid crystal variable retarder. The analyzing power of the resulting polarimeter was $>$ 0.999. The two beams passed nearly collinearly through a heated oven-cell arrangement; the Rb density range was $\sim 10^{11}$ cm^{-3} to 10^{13} cm^{-3}. The signal fluorescence was collected at right angles to the laser beams. Amplified photon counting signals were accumulated by a 100 MHz photon counter-discriminator system. Typical counting rates were $\sim 10^4$ s^{-1}.

The background-corrected signals for the two orthogonal laser polarizations are $S_{||}$ and $S_{\perp}$. These may be combined to form a linear polarization degree P_L, defined as $P_L = (S_{||} - S_{\perp})/(S_{||} + S_{\perp})$ which depends sensitively on ω_1 . Measurements were made over a ω_1 range of 200 cm^{-1} and were free of systematic variations due to laser intensity, Rb density, or initial hyperfine level. Final polarization measurements had an average statistical uncertainty of about $\pm$ 0.4 %. The measured polarization spectrum is shown in the lower section of Figure 1. For comparison purposes, the solid line in the figure represents the theoretical result when the ratio of matrix elements is R = 1. Departure from the curve are evident. The P_L spectrum was fit to theoretical expressions to obtain a ratio of transition matrix elements of R = 1.067(7), a strong departure from the nonrelativistic limit of R = 1. This fit is displayed in the upper half of the figure, where the deviation D of the P_L spectrum from R = 1 is shown.

Relativistic third-order many body calculations are in very good agreement with the measurements, permitting interpretation of the result as due to modification of Dirac-Hartree-Fock values by the differential effect of core polarization in the 5p multiplet components; the DHF values and the resulting electron correlation contribution to the reduced transition matrix elements account for nearly all the departure from the nonrelativistic value.

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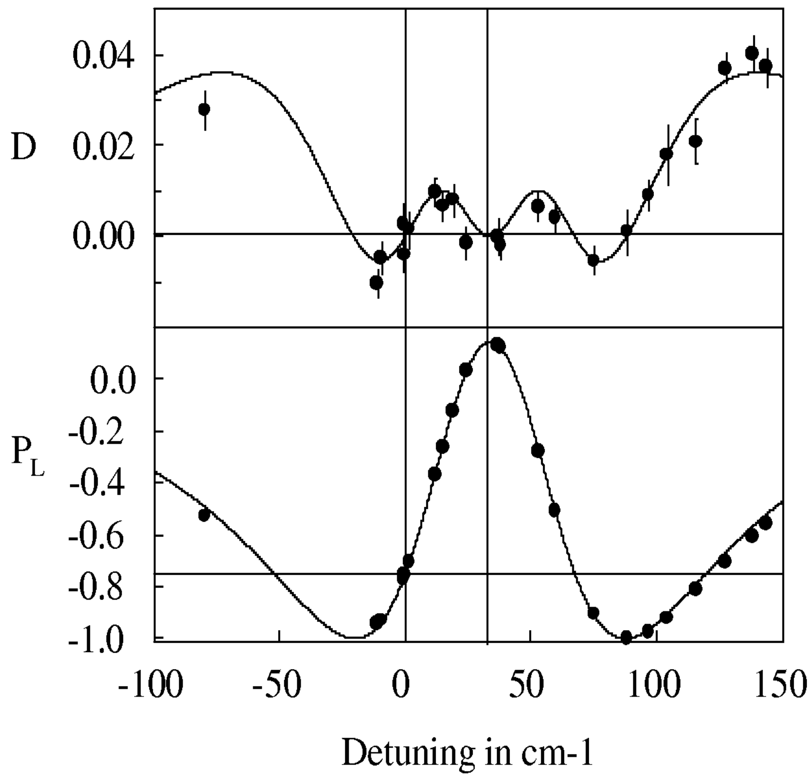

Figure 1: Measured linear depolarization P_L and deviation D as a function of detuning.