# Precise Laser Spectroscopy of Isotope shifts, Fine & Hyperfine Structure in $Li^+$ and Neutral Lithium

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Lithium has a number of properties that make it desirable for both experimental and theoretical study [1]. This includes transitions in the visible region where lasers readily operate. In the last decade there has been substantial theoretical progress principally from the development of the so called Hylleraas variational method to initially model two electron and more recently three electron systems [2]. The combined advances in experiment and theory have allowed tests of QED effects which scale as $Z^4$ where Z is the charge on the nucleus as well as the measurement of relative nuclear charge radii of isotopes [3].

Our group has developed a technique to measure isotope shifts as well as fine and hyperfine splittings whereby a laser beam modulated by either an acousto or electro-optic modulator is used to excite an ion or neutral atomic beam. Fluorescence detected by a photomultiplier is recorded as the laser is scanned across the resonance. Each transition generates multiple peaks in the resulting spectrum separated by the modulation frequency. The latter is specified to high accuracy by a frequency synthesizer allowing the frequency axis to be calibrated. Part of the laser beam is passed through an etalon to check for any scanning nonlinearity. We have determined the hyperfine splittings of the ground and first excited lithium state as well as the fine structure splitting of the 2P state and the isotope shifts of the $^{6,7}$Li D lines. The latter in conjunction with theory have determined the relative charge radius of $^{6,7}$Li with an accuracy of $2 \times 10^{-17}$ meter [3].

We are presently setting up an experiment to measure the fine structure splitting of the $Li^+$ 1s2p $^3$P state. This state is produced by first ionizing the lithium by colliding an electron beam with neutral lithium atoms. Some of the ions are excited to the 1s2s $^3$S metastable state that has a lifetime of nearly 1 minute. The 1s2s $^3$S - 1s2p $^3$P transition occurs at 548 nm and is laser excited. Our previous experiment measured the hyperfine splittings of the 1s2p $^3$P state and found excellent agreement with theory [4]. It also resolved a discrepancy between two previous measurements of the 1s2p $^3P_{1-2}$ fine structure splitting. The experimental accuracy was limited by the lineshape to about 1 MHz which resulted from the spread of ion velocities. Presently we are setting up an optical double resonance experiment. The ultimate accuracy is limited by the 3.7 MHz natural linewidth of the 1s2s $^3$S - 1s2p $^3$P transition. Hence, a determination of the line center of 0.1 % would measure the 1s2p $^3P_{0-1}$ transition to one part in $4 \times 10^8$. It would be of interest to compare such a result for the fine structure constant with the recent value as determined by the electron g-2 experiment [5].

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