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Analysis/Reduction of Residual Amplitude Modulation in Phase/Frequency Modulation by an EOM

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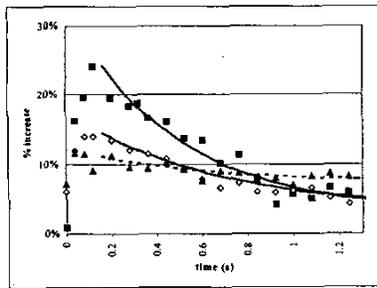


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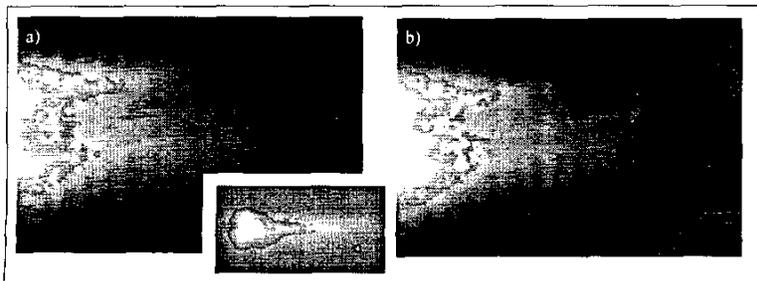
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QTuF25 Fig. 1. Graph showing the percentage increase in atomic fluorescence with the use of a far off resonance guide immediately after the guide is turned on. Exponential curves can be fitted to the decay of the pulse. 9 W (square points), 7 W (diamond points), and 5 W (triangular points) guides are shown.

tailed physical model that fits these experimental observations. We show a novel technique to increase the atom flux into such an oblique LG guide by placing an obstruction in the beam. The obstruction plane is imaged into the MOT such that the upstream wall of the guide is removed and only the downstream wall remains (the guide is 'C' shaped at LVIS). This technique significantly increases coupling efficiency by allowing LVIS atoms to enter the oblique guide (fig 2b). The guide regenerates by diffractive filling and becomes a cylinder again after it intercepts LVIS. Detailed simulations show the use of self-regenerating Bessel beams⁴ would allow guide reconstruction over only a few mm. This offers an important step towards creating an all-optical atom interferometer.

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QTuF25 Fig. 2. The result of an incident oblique LG guide on the LVIS beam is shown in a), the original LVIS beam is shown in the inset picture. The increase in coupling due to the use of an obstructed beam can be seen in b).

QTuF26

1:00 pm

Proposed Measurement of the Anapole Moment in Francium

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The anapole moment of a nucleus is a parity non-conserving (PNC), time reversal conserving moment that arises from weak interactions between the nucleons. It can only be detected in a PNC electron-nucleus interaction. We study the earlier suggestion¹ of directly measuring the probability of E1 transitions between the ground hyperfine states of an atom, allowed only through the anapole moment, with the present possibilities of atom manipulation.

Our apparatus for producing and trapping francium for parity non-conservation (PNC) experiments at the Stony Brook Superconducting LINAC can deliver 1.5×10^7 Fr that should permit upwards of 1.5×10^6 francium atoms in steady state in the capture trap. After accumulation in this first magneto-optical trap (MOT), we transfer the atoms to a different region where a far off resonance optical trap holds the cloud of cold atoms at the magnetic node of a standing microwave field created by a Fabry-Perot cavity.

The proposed experiment takes place in a controlled environment with well defined handedness. We use an interference technique to enhance a signal which changes as we change the handedness of the experiment. The atoms are initially prepared in a coherent superposition of two hyperfine states using a $\pi/2$ Raman laser pulse. The cavity microwave field is applied then to drive the anapole-induced E1 transition. Finally, the population in the excited state is measured making use of a cycling transition for very high detection efficiency.

The presence of the far off-resonance trap can cause unwanted effects that may mimic the parity violating signal. We analyze both red and blue detuned situations and find their advantages and disadvantages for the proposed measurements. We study other possible systematic errors involved in the measurement, such as imperfect polarization, stability requirements, along with steps to minimize them.

This work is supported by NSF. E.G. acknowledges support from CONACYT/Fulbright.

Reference

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QTuF27

1:00 pm

Analysis/Reduction of Residual Amplitude Modulation in Phase/Frequency Modulation by an EOM

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1. Introduction

Frequency modulation (FM) is a powerful tool for sensitive spectroscopy and laser frequency stabilization. The high potential modulation frequency and FM format makes it easier to achieve shot-noise limit detection.

Usually the laser frequency is modulated by an external frequency modulator such as electro-optic modulator (EOM). However to obtain a pure FM signal is not easy because of Residual Amplitude Modulation (RAM) arising by several effects: 1) etalon effects by light scattering within and at surfaces of the EOM crystal; 2) piezo-electric response of the EOM crystal, leading to beam steering and/or spatial position dither; 3) spatial inhomogeneity of modulation field in EOM crystal, leading to angular deviation of the beam and/or impure FM when part of the beam is selected; 4) and temperature dependence of the RAM associated with changes of the EOM crystal's optical path and birefringence. RAM can easily be in the percent domain, and degrades the sensitivity in the FM spectroscopy, and also gives undesirable frequency offsets from the frequency reference.

To solve the RAM problem, we measured and analyzed the RAM experimentally. A new active RAM suppression system is suggested.

2. RAM measurement

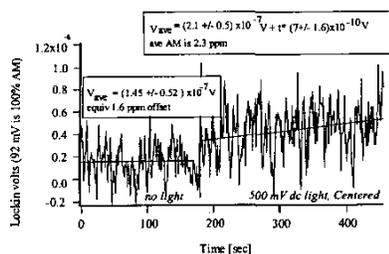
2.1 Experiment

The frequency doubled Nd:YAG laser was modulated by an AR-coated ADP crystal EOM ($7 \times 10 \times 70$ mm³, transverse r_{41} modulation) at a frequency of 220 kHz generated by a frequency synthesizer. The modulation coefficient was $\beta = 0.55$. To achieve high sensitivity, the photodetected signal containing RAM was down-converted to 10 kHz by driving a double balanced mixer with an auxiliary 230 kHz signal, and phase sensitively detected with a lock-in amplifier. The observed RAM signal relative to the FM was estimated to be -60 dBc, not far above the noise-level of the system using the resolution of 1 kHz.

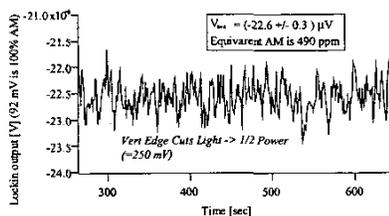
2.2 Analysis of RAM

Figure 1 shows observed RAM signal. In Fig. 1, the signals for no light and 360 μ W light (500 mV detector output) are compared. Comparing with 100% AM light, equivalent offset noise of 1.6 ppm and RAM of 2.3 ppm were obtained.

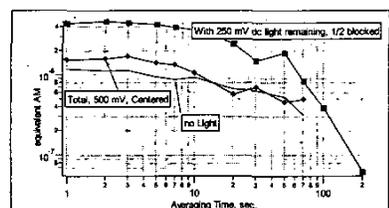
As shown in Fig. 2, when the vertical half side of the light beam was blocked, the RAM was much larger than when all light power was focused at the detector, which shows the RAM has a far-field spatial dependence along the axis of the



QTuF27 Fig. 1. RAM signal comparison with no light and 360 μ W light.



QTuF27 Fig. 2. Equivalent RAM signal of half blocked light beam.



QTuF27 Fig. 3. Time dependence of RAM signal noise.

modulation field. This spatial dependence of RAM is caused by beam angle swinging due to the slight inhomogeneity in the field applied to the EOM. It is NOT caused by output position dither due to a non-normal input angle to the EOM, nor to piezo-electric resonances.

Figure 3 shows the RAM time dependent stability. The observed RAM is stable even at an averaging time of 1 minute.

2.3 RAM reduction system

We suggest RAM reduction system with acoustic-optic modulator (AOM) amplitude stabilization system. A wide band servo can suppress RAM actively.

QTuF28 1:00 pm

Two-Photon Spectroscopy of Low-Lying States of Lithium: Energy Levels, Hyperfine Structure, and Isotope Shifts

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In recent years there have been rapid advances in theoretical models and calculational techniques for few-electron systems. Atomic structure calcu-

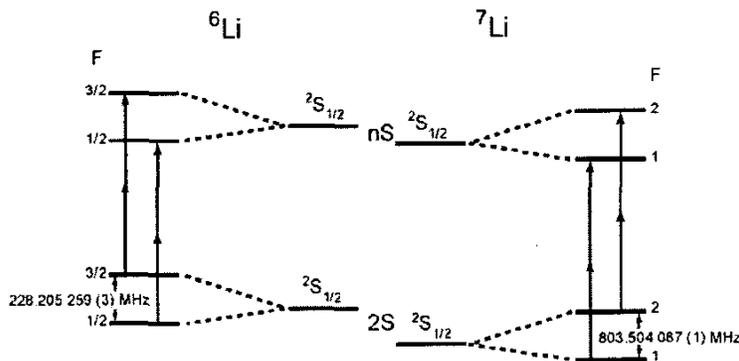
lations for He and He-like ions now include not only the non-relativistic energy but also relativistic and quantum electrodynamic (QED) contributions. The calculations are carried out with such high precision that they challenge the most accurate experimental measurements.

Extension of these calculations to three-electron systems has become a field of intense activity. A recent review article by King¹ summarizes the developments of theory over the past decade. Rapid advances in the calculation of energy levels, ionization potentials, fine- and hyperfine-structure, and isotope shifts for Li and Li-like ions have created a need for improved experimental data, as many measurements have uncertainties too large to be good tests of theory.

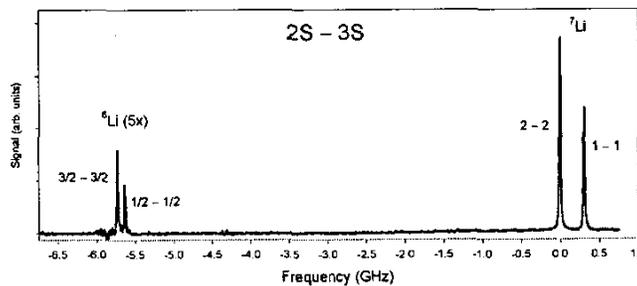
We have used non-resonant two-photon laser spectroscopy to observe the 2S–3S and 2S–4S transitions of Li. The structure of these levels is shown in Fig. 1. As the laser scans across each of these transitions, four are observed, as shown in Figs. 2 and 3. For each of these resonances we

manually set the laser to the peak of a transition. A computer controlled vacuum Fabry-Pérot wavemeter determines the laser frequency with respect to an I₂-stabilized He-Ne laser with an accuracy of a few parts in 10⁹. From these measurements we obtain precise transition energies between the ground state and excited state hyperfine levels. Because the ground state hyperfine splitting is known to extremely high precision,² we are able to calculate the excited state hyperfine constants for the 3S and 4S states with a precision of about 1 MHz for both isotopes. Our value for the 3S hyperfine constant resolves a discrepancy between an earlier high precision experimental determination³ and recent theoretical calculations.¹

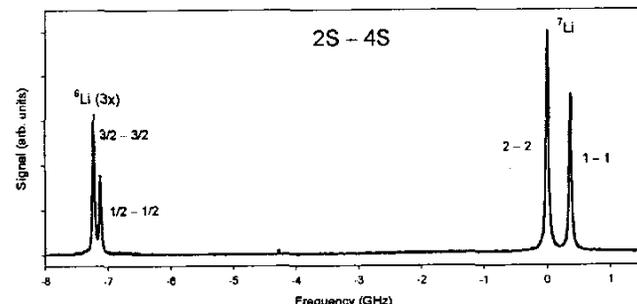
The centers of gravity of the 3S and 4S levels are determined with an absolute accuracy of better than 2 MHz. These are the highest precision measurements of the energy levels to date, reducing prior uncertainties by a factor of twenty. The transition isotope shift is also determined to bet-



QTuF28 Fig. 1. Structure and transitions for 2S–nS two photon transitions in lithium.



QTuF28 Fig. 2. 2S–3S two-photon spectra. The ⁶Li transitions are scaled by a factor of 5.



QTuF28 Fig. 3. 2S–4S two-photon spectra. The ⁶Li transitions are scaled by a factor of 3.