We collect absorption and fluorescence spectra (Fig. 4) for varying electric fields ranging from 0 to 7.1 kV/cm as the laser is scanned across the transition over 1200 data points. To each set of peaks, we fit Voigt profiles using a Levenberg-Marquardt residual minimization algorithm. The absorption spectrum is used to calibrate the frequency scale by phase modulating the scanned laser at 100 or 120 MHz so that first, second, and sometimes third order sidebands appear. We obtain a frequency-scale-calibration function by fitting a second-order polynomial to the five to seven modulation-induced peaks. We determine the difference between the Stark-shifted fluorescence peak and central absorption peak centroid from the field-free vapor cell. The Stark-shifted results are summarized in linear plots such as Fig. 5. Using second-order perturbation theory, the Stark shift $\Delta W$ can be written in terms of scalar polarizability $\alpha_s$ as $\Delta W = -\alpha_s E^2$, where $E$ is the applied electric field strength. For the resonant two-photon resonant transition, we measure the effective Stark shift of the $6P_{1/2} \rightarrow 6S_{1/2}$ transition $\Delta W_{\text{eff}}$:

$$\Delta W_{\text{eff}} = -(1/2)(\alpha_s + \alpha_p) E^2$$

where $\alpha_s$ is the scalar polarizability of the $6S_{1/2}$ ground state and $\alpha_p$ is the polarizability of the $6P_{1/2}$ state. We solve the equation for $\alpha_s$ using high precision measurements from the $6S_{1/2} \rightarrow 6P_{1/2}$ transition and the $6S_{1/2}$ polarizability. Our measurements of the $6S_{1/2}$ and $6S_{1/2}$ states are in good agreement with previous measurements of the $6S_{1/2}$ state and with theory for both states.

**Motivation**

Atomic cesium is important in a wide variety of high precision measurements including studies of fundamental symmetries or experiments that explore cold and long-range molecular interactions and optical cooling and trapping schemes used for quantum information processing. Our measurements in particular will be used in atomic structure calculations which are important for estimating black body radiation shifts, a significant limiting factor in next generation optical frequency standards. More precise atomic clocks will allow for new tests of fundamental physics and more accurate measurements of fundamental constants, and their time dependence as well as improved global positioning systems.

**Abstract**

We report the hyperfine-resolved scalar polarizabilities of atomic Cesium’s $8S_{1/2}$ and $9S_{1/2}$ states. The polarizabilities are determined using resonant two-photon laser-induced fluorescence spectroscopy in an effusive beam and a vapor cell by measuring Stark shifts. Electric fields are measured in the vacuum chamber while the frequency scale is referenced to the ground state splitting of rubidium through an optical modulation technique. The measured $8S_{1/2}$ scalar polarizability is 38370 ± 3804, which agrees well with previously reported theoretical and experimental values. The measured $9S_{1/2}$ scalar polarizability is 150700 ± 1100, which agrees within two standard deviations with theory, but we are unaware of previous measurements.

**Experiment**

The lasers and field-free vapor cell are secured on an optical table along with other necessary spectroscopic equipment such as mirrors, beam splitters, and various filters as well as opto-electronics such as modulators, amplifiers, and photodiodes. The laser beam is directed through a fiber optic cable into the vacuum chamber where the beam excites the effusive beam in a region between two parallel copper plates across which an electric field is applied. The biggest uncertainty in the experiment is the accurate determination of the electric field. Therefore, we measure the Stark shift for the $6S_{1/2} \rightarrow 6P_{1/2}$ transition and compare this to previous high precision measurements in the literature to determine a correction factor for our later experiments. In this calibration set-up (Fig. 2), a saturated-absorption spectrometer is used in which a pump beam passes through the vapor cell to excite a portion of the atomic population. One probe beam crosses the pump beam in the cell while a second probe beam passes straight through, both are then detected by photodiodes. The second probe beam is subtracted from the first to minimize the Doppler broadening caused by a distribution in the velocities of the atoms and we observe an absorption peak on an oscilloscope. To measure the polarizability of the $8S_{1/2}$ and $9S_{1/2}$ states, one laser is locked to the $6S_{1/2} \rightarrow 6P_{1/2}$ transition while a second laser is tuned to a wavelength that will excite the second absorption. Both lasers counter-propagate through a field-free vapor cell and the collimated effusive beam (Fig. 5) whose fluorescence signal is detected by a photomultiplier tube (PMT) as a dual fluorescence-absorption spectrum is generated (Fig. 6). The second laser doubles passes through an electro-optic modulator (EOM) that imposes sidebands equidistant from the central absorption signal. The second laser is stepped across the transition of interest and the output of a lock-in amplifier is recorded by an analog-to-digital converter in a microcomputer.