Measurement of Lifetimes and Electric Polarizabilities and Search for New Levels in Atomic Samarium

S. ROCHESTER, C. J. BOWERS, D. BUDKER, D. DEMILLE, A.T. NGUYEN, & M. ZOLOTOREV

PHYSICS DEPT., UNIVERSITY OF CALIFORNIA, BERKELEY, CA 94720-7300
& LAWRENCE BERKELEY NATIONAL LABORATORY
BERKELEY, CA 94720
We are measuring…

…the lifetimes and electric polarizabilities of certain low-lying odd parity levels of the samarium atom. (Fig. 1) In addition, we would like to find levels of the $4f\,^6s^2\,^5D$ term predicted by theory [1] but never seen. An earlier experiment [2] found three levels of this term and we will look for the two remaining levels.

We are measuring this because…

…this information is necessary to assess the feasibility of experiments to measure parity non-conservation (PNC) in the samarium atom. This effect may be enhanced due to small separation of opposite parity levels in samarium [3], however, current PNC experiments involving several transitions in samarium find no enhancement [4]. We will check other levels, including the missing levels of the $4f\,^6s^2\,^5D$ term, should we find them. In addition, measurements on these levels can be used to examine the possibility of doing experiments measuring time-reversal invariance in samarium [5].
Fig. 1. Low-lying configurations of Sm.
Results

We have measured lifetimes and tensor polarizabilities of the lowest-lying levels of the $4f^66s6p$ configuration:

| Term   | J  | Lifetime $\mu s$ (Expt.) | Lifetime $\mu s$ (Theory [9]) | Tensor Polarizability $(sec^{-1})/(V/cm)^2$ | Estimate of $|d|$ (e.a$_0$) | $|d_z|_{max}$ (e.a$_0$) |
|--------|----|--------------------------|-------------------------------|------------------------------------------|--------------------------|--------------------------|
| $^9G^o$ | 0  | 2.98(3)                  | 3.2                           |                                          |                          |                          |
|        | 1  | 2.43(2)                  | 2.9                           | 0.2388(3)                                | 0.41                     | 0.17                     |
|        | 2  | 2.05(1)                  | 2.6                           | 0.1716(5)                                | 0.24                     | 0.087                    |
|        | 3  | 1.82(1)                  | 2.4                           | 0.1713(8)                                | 0.14                     | 0.046                    |
|        | 4  | 1.70(2)                  | 2.4                           | 0.0587(4)                                | 0.36                     | 0.089                    |
| $^9D^o$ | 3  | 2.26(2)                  |                               | 0.473(1)                                 | 0.45                     | 0.15                     |
|        | 4  | 2.53(9)                  |                               | 0.4683(8)                                | 2.8                      | 0.84                     |
| ?      | 2  | 1.83(2)                  | 3.4                           | 0.2030(3)                                | 1.4                      | 0.40                     |

(Work in progress—errors do not include systematics.)
Experimental Setup

The setup is similar to our previous experiments in dysprosium [6,7] and ytterbium [8]. An atomic beam is produced by a resistively heated oven in a vacuum chamber, and light from a pulsed tunable dye laser is used to excite particular energy levels of the samarium atoms. Fluorescent light is detected with a photomultiplier tube, and optical filters are used to select light from a particular fluorescence decay channel. (Fig. 2)
Fig. 2
Experimental Procedure

- We have excited certain odd-parity states and measured fluorescence as a function of time to determine the state lifetimes (see Results.) (Fig. 3)

- We have found the electric polarizabilities of these states by measuring Stark-induced quantum-beats. An electric field is applied to the interaction region, and the fluorescence is measured as a function of time to determine the energy difference between Zeeman components. (Fig. 4) We have also observed Zeeman-induced quantum-beats produced by a magnetic field.

- To find missing levels, pulsed-cw saturation spectroscopy will be used. A cw laser will induce a known E1 transition, and fluorescence from the upper state will be monitored. Then the pulsed dye laser will be scanned through the predicted frequencies of the missing levels; when an M1 transition is induced, the ground state will be depleted, reducing the monitored signal. (Fig. 5)
Fluorescence from $4f^6 6s6p$, $J=2$ to $4f^6 6s^2 7F_3$ transition

$\tau = 1.96(2) \mu s$
Stark-induced quantum beats from $4f^66s6p \,^9G_1$ to $4f^66s^2 \,^7F_0$ transition
1. Tune cw laser to a known $E_1$ transition.
2. Use resonance fluorescence to monitor population of the ground state.
3. Scan pulsed dye laser frequency. When transition to the sought-after level is excited, the ground state population is depleted.

Fig. 5  Pulsed-cw saturation spectroscopy
References