Frequency measurement and isotope shift of the $4d^9 5s^2\ ^2D_{5/2} \rightarrow 4d^{10}6p\ ^2P_{3/2}$ transition in silver by laser heterodyne spectroscopy

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The silver atom is an interesting candidate for an optical frequency standard based on a narrow two-photon transition from the $4d^{10}5s\ ^2S_{1/2}$ ground state. Excitation of the $4d^9 5s^2\ ^2D_{3/2}$ state, whose natural width is about 4 kHz, requires two photons near 576 nm. Detection of this transition via cascade fluorescence should be straightforward. The narrower $4d^9 5s^2\ ^2D_{5/2}$ level (natural width less than 1 Hz) can be excited using two photons near 661 nm and was proposed as a frequency standard many years ago [1]. Detection of this transition is harder because the upper level is metastable.

Two groups are currently working in this field. The group of H. Walther at the Max Planck Institut für Quantenoptik, Garching, has cooled and trapped a sample of silver atoms using the 5s-5p transition at 328 nm [2], [3]. In our own laboratory, we employ a thermal atomic beam with the aim of obtaining an experimental linewidth of a few kilohertz for the $4d^{10}5s\ ^2S_{1/2} \rightarrow 4d^9 5s^2\ ^2D_{5/2}$ resonance using near collinear excitation.

At the last ICAP meeting, we presented some calculations of two-photon transition rates and schemes to detect atoms in the metastable level [4]. Since then, we have achieved detection of metastable silver atoms present in an atomic beam using laser induced fluorescence. In these experiments, a small fraction of atoms effusing from a tantalum oven was excited to the metastable $^2D_{5/2}$ level by electron bombardment. A dye laser was tuned to a hyperfine component of the $4d^9 5s^2\ ^2D_{5/2} \rightarrow 4d^{10}6p\ ^2P_{3/2}$ transition near 547.7 nm to transfer atoms from the metastable level to the short-lived $6p\ ^2P_{3/2}$ level. Atoms in this state were detected via the observation of the $4d^{10}6p\ ^2P_{3/2} \rightarrow 4d^{10}5s\ ^2S_{1/2}$ transition at 206 nm.

In a recent publication, we have described a measurement of the frequency, isotope shift and hyperfine structure of the 547.7 nm line which arose from this work [5]. Our aim was to check the results of measurements by other researchers [7], [6] since, from a knowledge of the frequencies of the 547.7 nm and 206 nm transitions, one can deduce the energy of $4d^9 5s^2\ ^2D_{5/2}$ level [6]. First-order Doppler broadening was reduced to about 10 MHz using laser excitation perpendicular to a collimated atomic beam. Local calibration of the frequency axis involved the use of a Fabry Perot cavity (free spectral range $\simeq$150 MHz) and the accurately known hyperfine splittings of the $4d^9 5s^2\ ^2D_{5/2}$ levels in ^{107}Ag and ^{109}Ag, the two stable isotopes of this element [8]. The frequency of each hyperfine component of the silver transition was linked to that of the hyperfine component a_1 of the resonance $R(22)27-1$ of the I_2 molecule.

Subsequently, we have confirmed the results of these measurements using laser heterodyne spectroscopy. Here, as before, one laser excited the silver transition in the atomic beam. This time however, following Dinger *et al.* [7], we detected the fluorescence at 328 and 338 nm resulting from the cascade decay of the $6p\ ^2P_{3/2}$ level, since this gave an eight times greater signal. A second dye laser was servo-locked to the above mentioned iodine resonance. The beat signal between the two lasers provided direct calibration of the frequency axis without the need to know the hyperfine splitting of the metastable levels of either isotope.

Latest results and a comparison with the work of other authors together with their implications for the energy of the metastable $4d^9 5s^2\ ^2D_{5/2}$ level will be presented at the conference.

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