Optical Production of Metastable Krypton

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Nobel gases, with their closed electronic shells, require large energy to transfer the atoms from the electronic ground state to the first accessible excited state. For this reason, it is common to use various discharge sources to transfer atoms from the ground state into excited states, in particular into a long-lived metastable state for optical manipulation. There are specific applications, however, that would benefit from optical methods over discharge methods to produce metastable atoms. These include Atom Trap Trace Analysis and velocimetry/wind tunnel experiments, where a discharge source is impractical.

The first stage in Atom Trap Trace Analysis is to transfer ground state Krypton or Argon atoms into a metastable state via a discharge source. Once in the metastable state a chosen isotope can be captured in a magneto optical trap and counted down to one atom at a time to determine an accurate isotopic abundance measurement. Replacing the discharge source with an alternative process using optical metastable atom production is appealing for two main reasons. First is the possibility of near 100% transfer efficiency to the metastable state which would reduce the sample size needed and also the time needed to analyze a sample. Current discharge sources have efficiencies of ~10^{-3}. The second is the removal of sample to sample contamination. Discharge sources create ions which can be embedded in the discharge tube itself. The embedded ions slowly diffuse out of the tube resulting in a contamination source for future samples. To minimize this contamination, the system is now “cleaned” between runs by running the discharge with another gas to drive some of the embedded sample from the tube. Replacing the discharge source with an optical method will largely prevent this contamination. This will improve the accuracy of the result and remove the time needed to clean the system between samples.

We are currently exploring two methods to optically produce metastable krypton atoms and plan to explore a third method in the future: These are: 1) resonant excitation using 123.5 nm light from the free electron laser at Jefferson Lab combined with 819 nm light from a laser diode, 2) a two-photon scheme using 193 nm light from an ArF excimer laser located at NASA, and 3) a two-photon scheme that uses 215 nm light. The NASA experiment is ongoing and the free electron laser experiment is currently scheduled for the middle of June 2012. For the FEL experiment, the laser is pulsed at 4.7 MHz with fundamental light production of ~1 μJ per pulse centered at 370.5 nm and with a spectral bandwidth of 1.5 nm and a third harmonic of the fundamental which has delivered energy of ~2 nJ per pulse centered at 123.5 nm with an expected spectral bandwidth of less than 1.5 nm (985 cm^{-1}). The 123.5 nm light (third harmonic) along with a 250mW, 819 nm laser diode will be used to optically produce the metastable atoms. The experiment in mid-June is designed to first test the effect of the fundamental beam from the FEL on an existing beam of metastable krypton atoms (created in a discharge). If the effect is found to be minimal, we will then attempt to use the third harmonic to produce the metastable atoms. Absent of negative effects (for example, ionization) from the fundamental, we expect an overall efficiency of $\sim 10^{-10}$.

The two-photon ArF excimer laser test is currently underway at NASA. Here, the excimer laser is pulsed at 10 Hz and is capable of up to 100 mJ of energy per pulse centered at 193.49 nm with a spectral bandwidth of 1.0 cm^{-1}. This scheme requires no additional lasers as the resulting two-photon excited state decays to the desired metastable state. We expect an efficiency of $\sim 10^{-3}$-10^{-2} per pulse.

We will report on the progress of our experimental program to investigate optical production of metastable krypton atoms using the methods described above.