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M. Harnafi, B. Dubreuil

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SOME PROPERTIES OF ATOMIC BEAM PRODUCED BY LASER INDUCED ABLATION OF Li TARGET

M. HARNAFI and B. DUBREUIL

Groupe de Recherche sur l'Energétique des Milieux Ionisés (GREMI), CNRS UA-831, Université d'Orléans, BP 6759, F-45067 Orléans Cedex 2, France

In this experiment, pulsed atomic beams produced in vacuum by laser induced ablation from lithium target are analyzed by laser-induced fluorescence (LIF). As an application of this atomic beam production technique, the $Z$-mixing processes induced in the $n = 9, 10$ Li Rydberg states by collisions with CO$_2$ molecules have been investigated.

The beam production developed in our experiment is based on front surface illumination of Li target with low energy laser pulses so that no detectable plasma cloud is formed. This approach is similar to the works of Olstad [1], Meng [2], Selter [3], Leismann [4] and Dreyfus [5]. The experimental set-up is shown in Fig. 1. Li target is placed in a vacuum vessel evacuated to a pressure of $10^{-6}$ Torr. Pulses from a TEA CO$_2$ laser working at 10 Hz with energy in the 0.2 - 0.7 J range are directed onto the target after spatial filtering and attenuation. The diameter of the laser beam on the surface is roughly 1 mm$^2$. Laser pulses consist of a main pulse of 150 ns duration and a 1 µs tail. About one half of the laser energy is contained in the main pulse. Taking into account spatial reduction and attenuation, the laser energy on the surface can be varied in the 2-7 mJ range (0.2 - 0.7 J/cm$^2$ fluence). This is low enough to avoid detectable plasma production. As a matter of fact, most of the laser energy is reflected from the surface, and only $\sim 4\%$ is absorbed.

Li atoms in the beam of ablated material are detected by LIF on the $2^2P - 2^2S$ transition. These measurements are performed as function of time by varying the delay between the CO$_2$ laser and the pulsed dye laser used to probe Li atoms. Such measurements are carried out at various distances from the target surface. This allows the determination of flight-time distribution.

Resolution is limited by the $\sim 1$ mm diameter of the probe laser beam. LIF signals are recorded using a 200 MHz transient digitizer [6]. Absolute Li density calibration is deduced from laser absorption. The laser line profile is analyzed at the output of the cell by the spectrometer connected to a gated integrator. The laser linewidth (0.8 Å) being larger than the absorption one, the absorption profile is measured and $n_{LI}$ is deduced from the absorption coefficient using an estimated absorption length. This results in an uncertainty of about 50%.

Combining LIF and absorption measurements, we obtain $n_{LI}$ as function of time at various distances from the target surface as shown on Fig. 2. Measured Li densities are in the $10^{12} - 10^{13}$ cm$^{-3}$ range depending on the absorbed laser energy (100 - 250 µJ). The position-time plot of the maximum density deduced from Fig. 2 exhibits a linear relation from which we deduce an atomic beam
velocity of \( \bar{v} = 7.4 \times 10^4 \) cm/s. It can be shown also that the lithium density varies with the distance \( d \) from the target surface according to \( n_{Li} \sim d^{-3} \) as it could be deduced from particle conservation assuming a conical emission.

The maximum particle flux density at the surface is estimated to be \( \Phi = n_{Li} \cdot \bar{v} = 5 \times 10^{16} \) cm\(^2\) s\(^{-1}\). Assuming a 1 \( \mu s \) emission time yields a total number of emitted atoms \( N \sim 5 \times 10^{11} \) per laser shot for 3.5 mJ incident energy.

As an application of this atomic beam production technique, we have studied the Li-CO\(_2\) collisional \( \ell \)-mixing process [6]:

\[
\text{Li}(n^2D) + \text{CO}_2 \rightarrow \text{Li}(n^2L > 2) + \text{CO}_2
\]

when a small amount of CO\(_2\) is introduced in the vessel.

This experiment could not be performed in the heat-pipe oven described in [6] due to the high reactivity of CO\(_2\) with Li. This difficulties are now circumvented by the renewing of Li atoms at each laser shot. The \( n^2 \) Li states are populated by two step laser excitation using two synchronously pumped dye lasers. The rate coefficients \( k \) for the \( \ell \)-mixing collisional processes are deduced from the slope of the LiF decay recorded for various CO\(_2\) pressures as explained in [6].

The values obtained for \( n = 9, n = 10 \) are \( k = 17 \times 10^{-9} \) and \( 15 \times 10^{-8} \) cm\(^3\) s\(^{-1}\) respectively.

References