Progress towards an Optical Isotope Shift Measurement of ^{11}Li

A. Dax[a], F.Schmitt[a], H. Wang[b], R. Kirchner[a], C. Bruske[a], H.-J. Kluge[a], T. Kühl[a], I. Tanihata[c], C. Zimmermann[d]

[a] GSI Darmstadt; [b] University of Tokyo, Tokyo, Japan; [c] RIKEN, Japan; [d] Universität Tübingen

The mean-square charge radius of ^{11}Li can only be determined by an optical isotope shift measurement on a suitable atomic transition. The accuracy demand for such an experiment is very high because the expected contribution of the nuclear volume to the isotope shift is only a fraction of the natural transition line width [1]. The sensitivity demand is as well very high because the signal-to-noise ratio is limited by the available number of nuclei. The maximum production yield in a beam of low emittance and of low energy spread, a prerequisite of this experiment, is currently only about 14000/sec provided by ISOLDE [2]. Resonance ionization spectroscopy [3] in combination with two-photon spectroscopy is our preferred method to encounter both problems. By making use of an unique excitation path we are able to ionize about 8 % of all atoms in the laser interaction volume without sacrificing resolution.

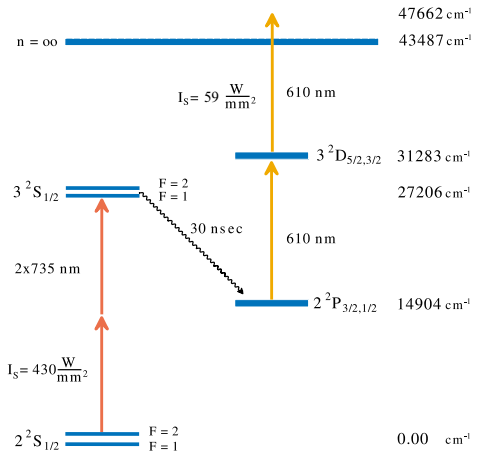

Figure 1: Lithium level scheme. The resonance ionization path and the required intensities are indicated.

Figure 1 shows the atomic energy level diagram of lithium and the excitation path together with the required laser intensities. The two-photon transition 2S $\rightarrow$ 3S provides a Doppler-free line width close to the natural line width of 2.7 MHz under optimized experimental conditions. It permits the excitation of all atoms in the laser interaction volume with the laser beam irrespective of their Doppler shifts. The hyperfine structure can be clearly resolved (see Fig. 2) and the necessary laser intensity of 430 W/mm^2 at 735 nm can be achieved with a strong continuous wave titanium sapphire laser beam in an external optical resonator.

The subsequent spontaneous decay from the 3S-state to the 2P-state (τ =30 msec) prevents the 3S-state as well as the 2S-state from being resonantly coupled to other energy levels by the strong ionizing laser beam. This isolation is a crucial demand. Otherwise the AC-Stark shift and the AC-Stark broadening [4] would sacrifice the high precision necessary for the 2S $\rightarrow$ 3S excitation step.

The final ionization step is again a two-photon transition non-resonant into the continuum but resonant via the intermediate 3D-level. This intermediate resonance enhances the ionization cross section several orders of magnitude especially because the resonant 2P $\rightarrow$ 3D transition is the strongest in lithium at all. The saturation power for this path is therefore only 59 W/mm^2.

Figure 2 shows a test result of the chosen excitation