Energy intervals between Rydberg states *nD* and *nF* in lithium-7

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Abstract. Using recently developed diagnostic technique we measured the frequency intervals between Rydberg states nF and nD ($n = 38$–48) of lithium-7 atoms. The obtained value of the quantum defect δ_F for Rydberg states nF is 0.000478(24).

The frequency intervals between Rydberg levels nF and nD ($n = 38$–48) of lithium-7 atoms were measured by using our diagnostic technique described in [1, 2]. Tunable uv laser was used for the two-step excitation of cold atoms in magneto-optical trap (MOT). The dependence of the resonance fluorescence on uv laser detuning was recorded. Due to residual electric field in MOT forbidden quadrupole transitions $2P$–nF [3] were observed together with dipole transitions $2P$–nD [2]. The laser frequency was controlled by calibrated wavemeter [4]. It allowed us to measure the frequency intervals with accuracy better than 0.5 MHz. In table 1, the values of the measured frequency intervals are presented.

Energy of Rydberg transitions can be calculated by the next well-known expression

$$E_{\mathrm{nl}} = E_I - \frac{R_m}{(n-\delta_l)^2}, \tag{1}$$

where E_I is the ionization energy for lithium atoms, $R_m = 109728.735348\ cm^{-1}$ is the mass-reduced Rydberg constant for the lithium-7 [5], δ_l is the quantum defect. Using the expression (1) it easy to get an equation for the frequency interval between Rydberg levels

$$\Delta\nu_{FD} = cR_m 10^{-4}\left(\frac{1}{(n-\delta_D)^2} - \frac{1}{(n-\delta_F)^2}\right). \tag{2}$$

Here $\Delta\nu_{FD}$ is the frequency intervals between nF and nD levels in MHz, c is the speed of light. In figure 1, experimental data and fitting curve are presented. The equation (2) was used as fitting formulae.

In figure 1, extrapolation of experimental data by equation (2) is shown. Free fit parameter was δ_F. Quantum defect in D-states was fixed as $\delta_D = 0.00192$ [6].

The fitting parameter obtained from extrapolation by equation (2) is $\delta_F = 0.000478(24)$. Quantum defect in highly-excited states is practically independent on principal quantum number n. For an arbitrary quantum state n the expression for the quantum defect can be written as [5,7]:

$$\delta_{\mathrm{nl}} = \delta_0 + \frac{\delta_1}{(n-\delta_{\mathrm{nl}})^2} + \frac{\delta_2}{(n-\delta_{\mathrm{nl}})^4} + \cdots. \tag{3}$$

Table 1. Experimental frequency intervals between the nD and nF levels of lithium-7 atoms.

n	38	39	41	44	48
$\Delta\nu_{FD}$, MHz	175.2	152.0	142.5	110.3	89.5

Table 2. Theoretical and experimental values of quantum defect in nF-states of lithium-7.

	Seipp 1995 [5]	Chen 2005 [8]	Our work
δ_0	0.00030862	0.0002931	0.000478(24)
δ_1	−0.00099057	—	—

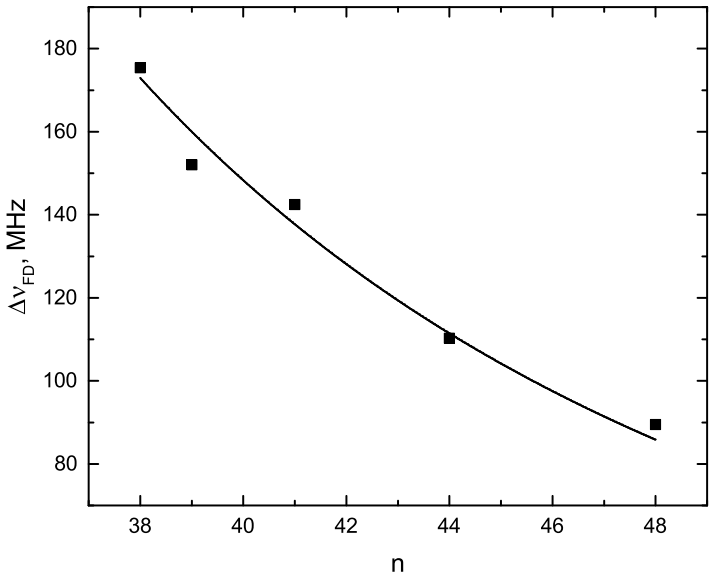

Figure 1. Experimental dependence of frequency intervals between nF and nD Rydberg levels on principal quantum number (squares) and fitting by equation (2) (solid curve).

In table 2, our data are presented along with experimental and theoretical results from other papers.

Experimental values from [5] were obtained for principal quantum numbers $n \leqslant 15$. Theoretical value from [8] was obtained on the base of experimental data from [9] for n less than 11.

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