Progress in the Measurement of 2s $^2S_{1/2}$-2p $^2P_{1/2}$ Transition Energies in Lithiumlike Heavy Ions[B,G]

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The accuracy of EUV spectroscopy applied to the measurement of 2s–2p transition energies in lithiumlike heavy ions has been improved to the $< 10^{-4}$ level of the relative wavelength uncertainty. In consequence, the measurements become sensitive to second–order QED contributions which result in the three electron system from screening. These effects scale with α^2 $(Z\alpha)^3$ and are more significant at intermediate Z. Experiments with the 2s $^2S_{1/2}$–2p $^2P_{1/2}$ transition especially and in comparison with theoretical data might provide an important test of QED in strong fields beyond the first order [1].

Using the GSI 5m grazing incidence spectrometer at the target area X3, 2s–2p transition energies in highly charged Ag and Xe ions were measured. The 1/2–1/2 fine structure transitions of Ag^{44+} and of Xe^{51+} were studied as well as a number of berylliumlike transitions. The spectrometer setup and the measurement procedure are described in detail in [2,3].

Calculated values result from RMBPT [4], the CI method [5] and the MCDF method [6]. Ab initio QED contributions were evaluated in [4] and [5] while in [6] a scaling of hydrogenic self energies was used. Good agreement between our results and all three calculations is observed within a 2 σ limit. Within σ, only the CI calculations agree with the measurements. With respect to this situation, a comparison of all published experimental results for intermediate and high Z with each other and with the calculations along the isoelectronic sequence is appropriate for revealing a Z dependence of uncalculated terms.

Such a comparison is presented in figure 1. It shows the difference between experimental and calculated transition energies as function of Z with Z > 25. Experiments with a precision of better than 2 % of the QED contribution are included (for the references see [3]). This difference is normalized to the absolute value of the QED contribution in order to show the QED sensitivity of the experiments. The three mentioned calculations are considered at Z values where they present a transition energy [4,5,6]. It is remarkable that the overall agreement between experiment and the MCDF calclulation is very good since it does not contain an ab initio QED treatment. The CI calculation shows no systematic deviation from experiment while for the RMBPT results a 1/Z dependence of the normalized difference between experiment and calculation might be deduced. It could result from the Z^3 dependence of uncalculated screening terms divided by the Z^4 dependent QED contribution. For a more detailed discussion see [3], where we concluded that our presented results for the 1/2–1/2 transition in lithiumlike Ag^{44+} and Xe^{51+}, and the measurement of the transition energy for the 1/2–3/2 transition in Bi^{80+} [7] are at present the only measurements which are sensitive to higher–order QED contributions.

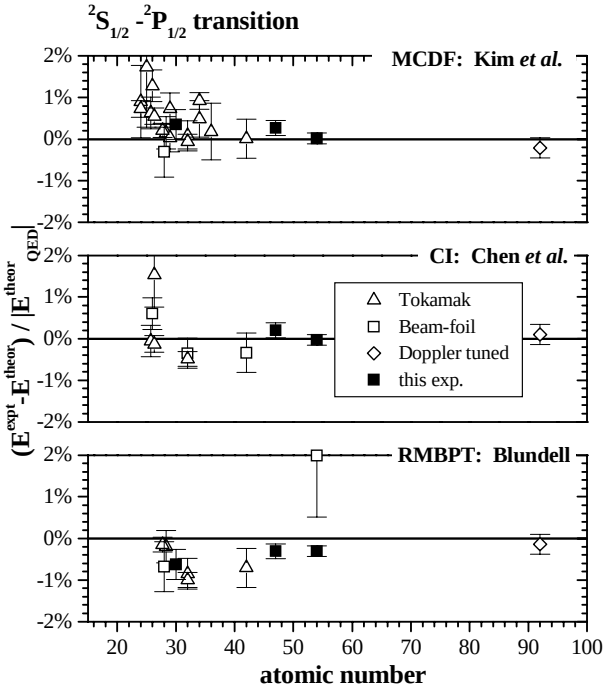

Fig. 1: Normalized difference between experimentally determined and calculated 2s $^2S_{1/2}$–2p $^2P_{1/2}$ transition energies along the Li isoelectronic sequence. Data points are shown only where theoretical and experimental values exist for the same atomic number. (References of experiments in [3]. Calculations are from [4,5,6].)

[1] I. Lindgren, Physica Scripta; to be publ.; Invited talk IX. Internat. Conf. of the Physics of Highly Charged Ions, Bensheim, Sept. 1998
[2] U. Staude et al., Phys. Rev. A; to be publ.
[3] Ph. Bosselmann et al., Phys. Rev. A **59** (1999); to be publ.
[4] S.A. Blundell, Phys. Rev. A **47**, 1790 (1993)
[5] M.H. Chen et al., Phys. Rev. A **52**, 266 (1995)
[6] Y.–K. Kim et al., Phys. Rev. A **44**, 148 (1991)
[7] P. Beiersdorfer et al., Phys. Rev. A **52**, 2693 (1995)