The *g* Factor of Lithiumlike Silicon ^{28}Si^{11+*}

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The relativistic electron-electron interaction can be stringently tested by high-precision measurements of the gyromagnetic factor (*g* factor) of the valence electron bound in many-electron systems. Especially three-electron ions allow for a highly-sensitive test since they can be theoretically predicted to a high accuracy. To this end the *g* factor of the 2*s* valence electron bound in lithiumlike silicon ^{28}Si^{11+} has been determined with an uncertainty of $\delta g/g = 1.1 \cdot 10^{-9}$ [1], which is the most precise *g* factor measurement of a three electron system to date.

The *g* factor measurement

For the *g* factor measurement a single ion was stored in a cryogenic triple Penning trap setup for several months [2]. To determine the *g* factor via

$$g = 2\frac{\nu_L}{\nu_c}\frac{q}{M_{ion}}\frac{m_e}{e} \qquad (1)$$

the Larmor frequency ν_L and the free cyclotron frequency ν_c of the ion have to be measured, while the mass of electron m_e and ion M_{ion} are known from other high-precision experiments. The free cyclotron frequency can be determined by measuring the three eigenfrequencies of the ion in a first Penning trap. Simultaneously, microwaves close to the expected Larmor frequency are irradiated into the trap to induce spin flips. To determine the spin orientation with the continuous Stern-Gerlach effect, the ion is transported to a second Penning trap, where a magnetic inhomogeneity couples the spin orientation to the axial motion. Comparing the spin orientation to the orientation determined in the last cycle reveals if a spin flip was successfully induced. After several hundred cycles the spin flip probability as a function of the measured frequency ratio $\Gamma = \nu_L/\nu_c$ yields a *g* factor resonance as shown in Fig. 1.

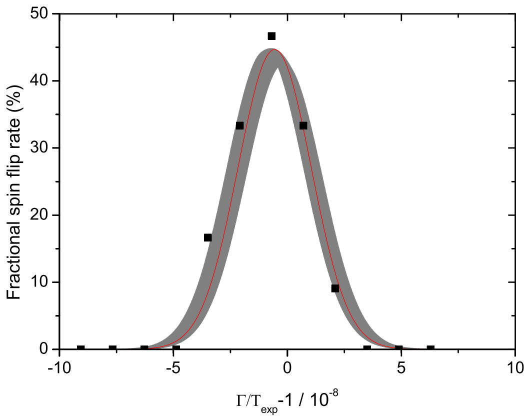

Figure 1: *g*-factor resonance of a single ^{28}Si^{11+}-ion.

We have recorded three resonances with different microwave powers to check for related systematic shifts. The experimental result g_{exp}=2.000 889 889 9(21) is in excellent agreement with the theoretical value g_{exp}=2.000 889 909(51). The comparison between experimental and theoretical *g* factor confirms the many-electron contribution on the level of 10^{-4}, which is the most stringent test of relativistic many-electron calculations to date. Since the experimental value is by more than one order of magnitude more precise than the theoretical value, any improvement of the theoretical *g* factor will immediately improve this test.

Outlook

For highly sensitive tests of quantum electrodynamics with heavy ions the achievable theoretical precision is limited by unknown nuclear parameters. A measurement of both lithium- and hydrogenlike ions allows to cancel the contributions of the nuclear parameters to a large extent, hereby significantly increasing the stringency of the test [3]. Moreover, if combined with a measurement of the boronlike charge state, the fine structure constant α can be determined with a comparable uncertainty as the current value [4].

Having finished the *g* factor measurement of lithiumlike silicon, a *g* factor measurement of hydrogenlike carbon was started, aiming for an improvement of the precision of the electron mass by one order of magnitude.

References

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