# First Laser Spectroscopic Observation of the Hyperfine Splitting in $^{209}Bi^{80+}$

*M. Lochmann[1,2], Z. Andjelkovic[1,2], B. Botermann[1,2], M. Bussmann[6], A. Dax[5], N. Frömmgen[2], C. Geppert[2], M. Hammen[2], V. Hannen[4], R. Jöhren[4], Th. Kühl[1,2], Y. Litvinov[1], J. Mader[4], R. Sánchez[1,2], Th. Stöhlker[1,3], R. Thompson[8], A. Volotka[9], C. Weinheimer[4], W. Wen[7], E. Will[2], D.F.A. Winters[1,3], W. Nörtershäuser[1,2], the E083 collaboration[1]*

[1]GSI Helmholtzzentrum, Darmstadt, [2]Universität Mainz, [3]Universität Heidelberg, [4]Universität Münster, [5]University of Tokyo, [6]Helmholtzzentrum Dresden-Rossendorf, [7]IMP Lanzhou, [8]Imperial College, London, [9]TU Dresden

Laser spectroscopic measurements of the ground state hyperfine splitting (HFS) in hydrogen-like heavy ions are of great interest because they can be used to test QED effects in extremely strong electric and magnetic fields. However, the interpretation of the experimental values is difficult since the uncertainty of the contribution of the nuclear magnetization distribution (Bohr-Weisskopf effect) conceals the size of the QED contributions.

It has been suggested to overcome this limitation by measuring the HFS in both hydrogen-like and lithium-like heavy ions of the same species [1]. Thus, tests of the QED effects on the level of a few percent become feasible [2].

Bismuth is the only stable isotope where the ground state hyperfine transitions of both hydrogen-like and lithium-like ions are in a range accessible to laser spectroscopy. The HFS-transition wavelength for hydrogen-like bismuth ($^{209}Bi^{82+}$) has already been measured with a relative accuracy of $1.6 \cdot 10^{-4}$ by Klaft *et al.* [3], but the direct search for the transition in lithium-like Bi at the ESR was so far unsuccessful.

Finally, in the beam time in August this year, we have observed the transition for the first time. Several $10^8$ ions of $^{209}Bi^{80+}$ were stored in the ESR at a fixed energy of $\approx 400\,\mathrm{MeV/u}$ $(\beta \approx 0{,}7)$ and bunched at the second harmonic of the revolution frequency using an RF of $\approx 4\,\mathrm{MHz}$. Due to the relativistic Doppler shift, the HFS-transition could be excited with the laser wavelength scanning at $\lambda \approx 640\,\mathrm{nm}$ in collinear geometry, instead of $\lambda \approx 1555\,\mathrm{nm}$ in the rest frame of the ion. We used a Sirah "Cobra Stretch" dye laser, pumped by a pulsed, frequency-doubled Spectra-Physics "Quanta Ray" Nd:YAG-laser. The laser pulses were spatially and temporally overlapped in the electron cooler section with one of the two ion bunches. This bunch was used as signal bunch, whereas the other one served as a reference to correct for ion-beam-induced background. The detection took place on the opposite side of the ESR, near the gas target section.

The moveable mirror, especially designed and built for this experiment [4,5] turned out to be a key improvement compared to the previous beam times. It consists of a parabolic copper plate, centred in the beam line. The ion beam passes through a slit of $\varnothing 30\,\mathrm{mm}$ in the mirror. The mirror was retracted from the beam line before ion injection to the ESR, and moved in again after $\approx 15\,\mathrm{s}$ of electron cooling. The fluorescence photons emitted by the ion bunch were directed by the mirror to a photomultiplier tube. This setup proved to be significantly more efficient than the old segmented mirror section.

Data acquisition was based on a VUPROM [6] (a field programmable gate array, FPGA), designed and programmed at the experimental electronics department at GSI. A time stamp was assigned to each registered photon, synchronized to the bunching RF with a resolution of 300 MHz. In the analysis, the photon counts belonging to the reference bunch were subtracted from the signal counts. A plot of the observed resonance is shown in fig. 1. Analysis is still ongoing.

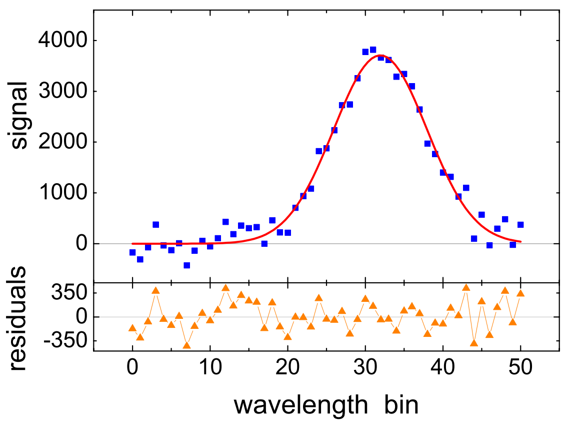


Figure 1: Background corrected signal of the HFS of $^{209}Bi^{80+}$ accumulated during ≈1 h of beam time at the ESR. The squares are data, the line is the result of a Gaussian fit and the triangles are the fit residuals.

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