Improving the limits of the recent Local Lorentz Invariance test at the ESR

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Since a few years we have been performing an experimentaltest of Lorentz Invariance at the ESR. As reportedpreviously [1, 2] time dilation was tested as an explicitaspect of Lorentz Invariance at the ESR using laser spectroscopyon $^7Li^+$ions at a velocity $\beta = 0.34$. The restframe excitation frequency ν_0 of an electronic transition inthe moving ion appears Doppler-shifted according to

$$\nu = \nu_0 \cdot \gamma(1 - \beta\cos\vartheta),$$

when observed under an angle ϑrelative to the laser directionin the laboratory frame. $\gamma$is the time dilation factor.For a setup with parallel and antiparallel aligned laserbeams this equation simplifies to $\nu_{\mathrm{a,p}} = \nu_0 \cdot \gamma \cdot (1 \pm \beta)$,respectively, and for the case Lorentz Invariance holds, thethree frequencies ν_0, $\nu_{\mathrm{a}}$and ν_{p}fulfill the relation

$$\frac{\nu_{\mathrm{a}} \cdot \nu_{\mathrm{p}}}{\nu_0^2} = 1\ ,$$

which is independent of the angle $\vartheta$and the velocity β.

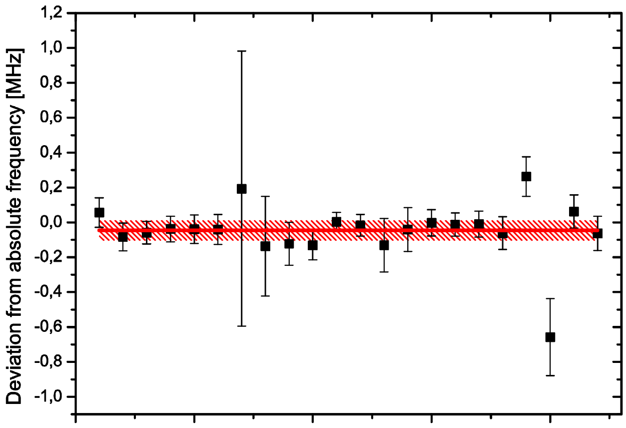

Figure 1: Results from several measurements with theTi:Sa laser stabilized on $^{127}I_2$. The vertical axis shows thedeviation from the assigned transition of the frequency stabilization.The red line is the mean value and the shadedarea is the 1-$\boldsymbol{\sigma}$ uncertainty.

Since we are searching for deviations from the equation above,precise knowledge of the frequencies of the excitation lasers is necessary. To provide a reliable estimation forthese uncertainties the stabilized frequencies of both laserswere investigated with a frequency comb referenced to aGPS disciplined Rb clock.For this purpose, the breadboards with the laser systemsthat were used during our beam times at GSI were shippedto the institute for nuclear chemistry at the University ofMainz. The systems consist of a diode laser for the anti parallellight with frequency ν_{a} and a titanium-sapphire laser(Ti:Sa) followed by a second harmonic generation cavitywhich produces the light for parallel excitation with frequencyν_{p}. The diode laser frequency was stabilized to the $^2S_{1/2} \rightarrow {}^2P_{3/2}$ transition in atomic ^{87}Rb and the frequencyof the Ti:Sa laser was stabilized to the P(42)1-14 transitionin molecular $^{127}I_2$. For the diode laser as well as forthe Ti:Sa an am/fm saturation spectroscopy [3] scheme wasused as stabilization setup.In both cases the heterodyne frequency between laserand the nearest comb mode was recorded. From severaltime series of the heterodyne frequency under varying experimentalconditions, the average value of the absolutefrequency and its uncertainty were extracted. For the diodelaser we found

$$\nu_{\mathrm{DL}} = (384\ 228\ 116.18\ \pm\ 0.64)\mathrm{MHz}$$

and for the Ti:Sa

$$\nu_{\mathrm{Ti:Sa}} =\ (388\ 605\ 083.66\ \pm\ 0.06)\mathrm{MHz}$$

which are in excellent agreement with the literature valuesof 384 228 116.12 MHz [4] and 388 605 083.71 MHz [5],respectively. The uncertainties of these values will be usedin the evaluation of the SRT test experiment.

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