Contribution ID: **16** Type: **not specified**

Lifetimes, Level Energies and Light Shifts in a single trapped Ba^{+} ion

A precise measurement of Atomic Parity Violation (APV) in atomic systems aims at the determination of electroweak mixing Weinberg angle ($\sin^2\theta_W$) at low momentum transfer. The precision to which $\sin^2\theta_W$ can be determined depends on the accuracy of the knowledge of the atomic structure of the trapped and laser cooled simple alkaline earth ionic systems like Ba^+ and its intrinsic sensitivity to high precision measurements. Available information on the atomic system Ba^+ and experimental inputs for verification of recent improved calculations for Ba^+ wavefunctions is a part of this research work. The information on the lifetime of the long lived $5d^2D_{5/2}$ state, level energies and light shifts in the presence of the additional laser field in single Ba^+ ion is provided with a focus on the experimental conditions and their influence on the measurements. This information will be further implemented towards APV. A single ion localized to better than one optical wavelength is a necessary prerequisite for such a precise APV measurement. A single Ba^+ ion experiment has been constructed and the frequency stabilization techniques for the employed laser systems have been implemented. The lifetime $D_{5/2}$ of the metastable $5d^2D_{5/2}$ state is extensively studied both in single and multiple ions in this setup. These measurements provide for detailed and precise understanding of the intrinsic atomic structure and enables extraction of atomic wavefunctions of the involved states. High resolution frequency spectroscopy of the laser cooling transitions $6s^2S_{1/2}$-$6p^2P_{1/2}$ and $5d^2D_{3/2}$-$6p^2P_{1/2}$ in Ba^+ with single and multiple trapped and laser cooled ions permits the determination of absolute frequencies of the relevant transitions to 100 kHz accuracy which is more than 100 times better than earlier measurements. This gives an excellent understanding of the complex spectra of Ba^+ with an Optical Bloch Equation (OBE) 8-level system. The spectra are exploited towards observation of light shifts in the $6p^2P_{1/2}$-$5d^2D_{3/2}$ transition in a single Ba^+ ion for the first time and the systematic effects have been investigated.

The vector and tensor light shifts of the individual Zeeman components for different $6s^2S_{1/2}$-$5d^2D_{3/2}$ transitions in Ba^+ are observed. Further, extensive studies of these vector and tensor light shifts have been initiated and are currently in progress. This is an excellent step towards light shift determinations in the Zeeman sublevels of the ground state of a single ion which is crucial for the precise determination of APV.

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