High precision spectroscopy of single $^{138}Ba^+$ ions

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We investigate single trapped, laser cooled Ba^+ and Ra^+ ions as ideal candidates for high precision measurements of the weak mixing angle in atomic systems; furthermore, the same experimental setup can be employed to build an atomic clock with a fractional frequency uncertainty of 10^{-18} [1]. For these applications of high precision spectroscopy a good understanding of the optical line shapes involved is indispensable.

We have studied the transition frequencies between low-lying energy levels in a single trapped $^{138}Ba^+$ ion using laser spectroscopy [2]. The levels of this alkaline earth ion form a Λ-type system, where two lasers are used for laser cooling and probing. A frequency comb that is referenced to a GPS-disciplined Rb clock is used to control the laser frequencies. By extracting the one-photon and two-photon components of the line shape using an eight-level optical Bloch model (see Fig. 1), we achieved order 100 kHz accuracy for the frequencies of the transitions between the $6s\,^2S_{1/2}$, $6p\,^2P_{1/2}$ and $5d\,^2D_{3/2}$ levels. This forms an improvement in the absolute accuracy of more than two orders of magnitude.

In addition, the lifetime of the metastable levels of these ions provides a probe of the atomic structure and can also be used as a sensitive diagnostic for perturbations to the ion. We have used quantum jump spectroscopy of a single trapped Ba^+ ion to measure the lifetime of its $5d\,^2D_{5/2}$ level [3].

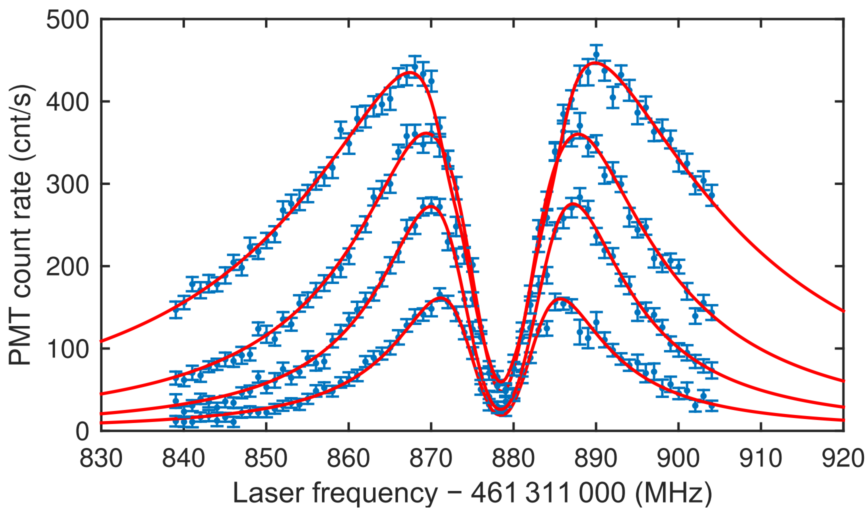

Figure 1: *Spectra of the $5d\,^2D_{3/2}$ – $6p\,^2P_{1/2}$ transition in a single $^{138}Ba^+$ ion recorded for different laser light intensities* [2]. *The dip in the spectra is caused by a two-photon effect when both lasers driving the ion transitions are on resonance. The solid lines correspond to the results of fitting the optical Bloch model to the data. The widths of the spectra display power broadening.*

References

[1] M. Nuñez Portela *et al.*, Appl. Phys. B **114**, 173 (2014)

[2] E. A. Dijck *et al.* (2015), `arXiv:1504.01285 [physics.atom-ph]`

[3] A. Mohanty *et al.*, Hyperfine Interact. (2015), `doi:10.1007/s10751-015-1161-9`