Indium single-ion optical frequency standard

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Laser-cooled ions in radiofrequency traps are the atomic systems that allow the highest fractional resolution in optical or microwave spectroscopy. They can serve as references in highly stable frequency standards and also enable precise tests of fundamental physics. We present recent results on our In^+ optical frequency standard, based on the $5s^2\ ^1S_0 \rightarrow 5s5p\ ^3P_0$ transition at 236.5 nm wavelength [1, 2]. This transition has a natural linewidth of only 0.82 Hz and is highly immune to systematic frequency shifts.

A single indium ion is stored in a miniature Paul-Straubel trap and laser cooled using the $^1S_0 \rightarrow\ ^3P_1$ transition at 230.6 nm. Sideband laser cooling brings the ion to the vibrational ground state of the trap potential and we have measured a temperature as low as 60 μK [3]. The clock transition is excited using a frequency quadrupled Nd:YAG laser at 946 nm. Excitation of the $^3P_0$ state is detected in optical double resonance via the quantum jumps in the fluorescence on the cooling transition. A fractional resolution of $1.3 \cdot 10^{-13}$ has been achieved so far (linewidth $\approx$ 170 Hz at 1267 THz), limited by the linewidth of the Nd:YAG laser. We measured the lifetime and the Landé g-factor of the metastable $^3P_0$ level. Both quantities are of relevance for the frequency standard: The natural linewidth is important for the achievable short term stability and the Zeeman shift (of 224 Hz/G) might limit the long term accuracy and reproducibility. It seems feasible to control all systematic shifts at the millihertz level, leading to an accuracy in the range of 10^{-18}. The absolute optical frequency of the $^1S_0 \rightarrow\ ^3P_0$ clock transition has now been measured with an uncertainty of only $2 \cdot 10^{-13}$ using a frequency chain and a methane-stabilized HeNe laser that was calibrated with a cesium clock [4]. Work is under way to improve the frequency stability of the clock laser system. A new system based on a quasi-monolithic Nd:YAG laser and frequency doubling using periodically poled KTP is presently developed.

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[4] see poster by J. v. Zanthier et al. at this conference.