Towards an optical frequency standard based on a single Ca^+ ion in a miniature trap

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Among the ions proposed for a frequency standard in the optical domain, Ca^+ is one of the most favorable candidates due to its wavelengths accessible with all-solid-state laser systems. This allows to imagine an ultimate experimental setup being simple and compact. The $4s\,^2S_{1/2}$ – $3d\,^2D_{5/2}$ electric quadrupole transition at 729 nm with a natural linewidth below 1 Hz serves as clock transition, while laser cooling on one of the resonance lines, $4s\,^2S_{1/2}$ – $4p\,^2P_{1/2}$, is carried out at 397 nm. To obtain the small spectral linewidths necessary for a frequency standard performance, it is essential to reduce the residual Doppler broadening caused by the rf heating in the Paul trap. The 1st order Doppler broadening of a single ion can be eliminated in the Lamb-Dicke regime where the ions amplitude of motion is inferior to the emitted wavelength. The main condition for the access of this frequency modulation regime is a high motional frequency of the trapped ion. This is more easily obtained in a low capacitance device and thus traps with reduced dimensions are required.

We have set up a miniature ion trap of the Paul-Straubel-type [1]. It consists of a cylindrical molybdenum ring of 1.4 mm inner diameter being surrounded by four compensation electrodes. The confinement frequency is close to 12 MHz, giving rise to a frequency of motion in the MHz range. The stored ions are observed by a photomultiplier in the photon-counting mode as well as by an intensified CCD camera, permitting the visualization of their spatial behavior.

One way to obtain the laser cooling wavelength at 397 nm is frequency doubling of a 794 nm laser with a non-linear crystal. Our aim is to replace the pumping TiSa-laser by a high-power multimode diode laser injected by a spectrally pure single-mode master laser placed into an external cavity [2]. To produce radiation at 729 nm we use a multi-mode diode laser with relatively low light power put into an external cavity. Making use of the Pound-Drever-stabilisation method on an ULE-cavity of very high finesse will result in a laser linewidth in the kHz-range.

Progress on the characterization of a trapped single ion as well as on the generation of the involved wavelengths exclusively by solid-state lasers will be reported at the conference.

[1] M. Knoop, M. Vedel, M. Houssin, T. Schweizer, T. Pawletko and F. Vedel, *Proceedings of the Conference on Trapped Charged Particles and Fundamental Physics* **CP 457**, p. 365-368 (eds. Daniel H. Dubin and Dieter Schneider), The American Institute of Physics (1999)

[2] T. Pawletko, M. Houssin, M. Knoop, M. Vedel and F. Vedel, *Opt. Comm.* **174** 223 (2000).