Application Note

Using an Atomic Nucleus for Precise Time Measurement

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The current definition of time uses a transition between two atomic energy levels in cesium to determine with relatively high precision how long a second lasts. Cesium atoms are indistinguishable quantum particles and are therefore completely identical all over the world which offers a totally reproducible system and is therefore ideal as a frequency/time standard. One of the most essential tools for manipulating atoms is the Laser since it allows e.g. the output of light with a very exact frequency or pulses with very short duration.

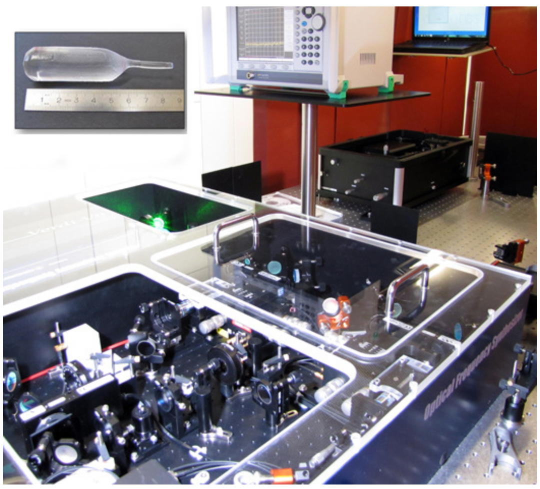

Figure 1: Optical table with frequency comb, Thorium-doped crystal

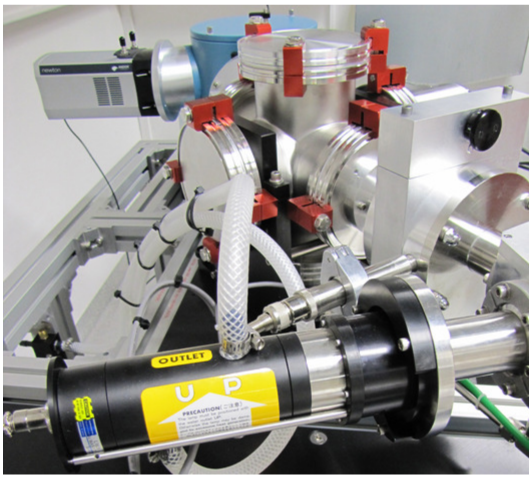

Figure 2: UV spectrometer (Mc Pherson)

Nuclear transitions, i.e. transitions between energy levels of the atomic “core”, can provide some advantages compared to atomic transition: some are much more stable against external perturbations and provide transition frequencies which are much more exactly defined (and therefore allow a more precise determination of time). The energies necessary for manipulating nuclei are usually by orders of magnitude higher than what is accessible by Lasers and are typically provided by particle accelerators.

We want to make use of the isotope Thorium-229 which is predicted to offer the unique possibility of a low-energy nuclear transition which can be driven by a UV-Laser. The expected properties of the transition (which has only been measured indirectly) makes this transition an excellent candidate for a new time standard, with a potential to outperform existing clocks by orders of magnitudes. In addition to precise measurement of time, Thorium-229 is excellently suited for measuring if our fundamental constants are really constant over time and space.

A frequency comb is currently set up which will be transferred to the 160 nm region by a high-harmonic generation build-up cavity and will be used as a precision measurement tool for comparison of the nuclear transition to other frequency standards.

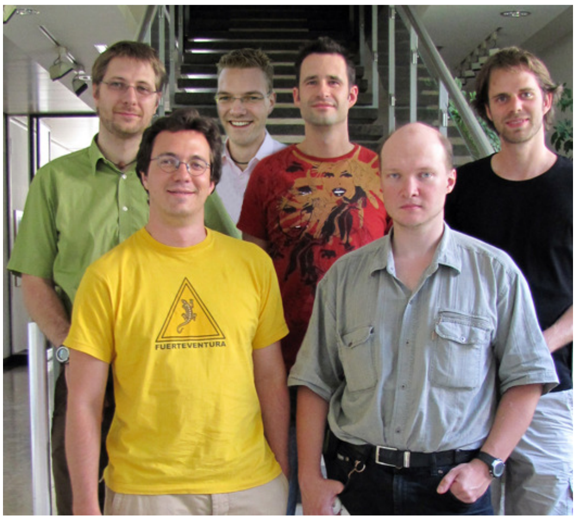

Figure 3: Group photo (left to right: Johannes Sterba, Georg Winkler, Georg Steinhauser, Thorsten Schumm, Georgy Kazakov, Matthias Schreitl)

Weblinks:

https://www.nuclock.eu/