$^{171}Yb^+$ Optical Frequency Standards

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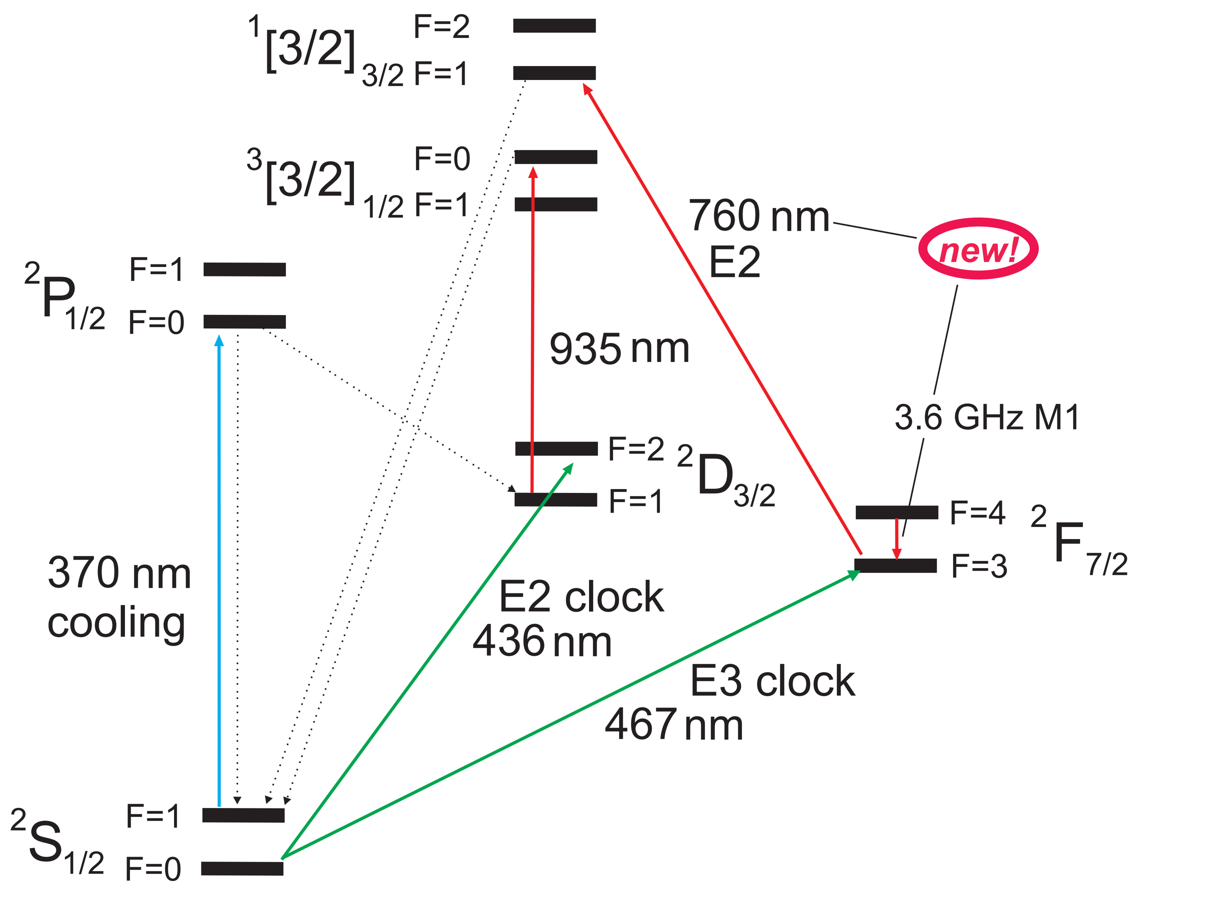
E3 clock transition at 467 nm

- natural linewidth: nano-Hertz range !
- excitation is accompanied by large light shift due to coupling to other levels
- transition frequency has been measured with uncertainty $2 \cdot 10^{-14}$ [K. Hosaka et al., PRA 79, 033403 (2009)]

Recent results:

- implementation of a new efficient repumping scheme from the $^2F_{7/2}$ state
- excitation of E3 transition using a diode laser system with high frequency and power stability [1]
- high-resolution spectroscopy with 7 Hz FWHM



E2 clock transition at 436 nm:

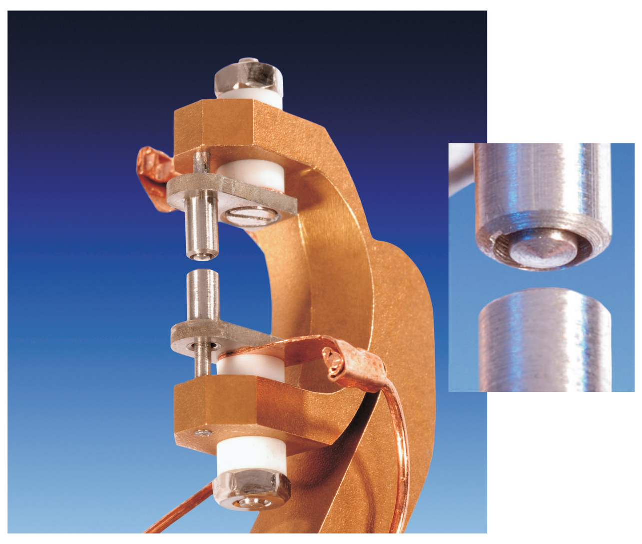
- natural linewidth 3.1 Hz
- secondary representation of the SI second

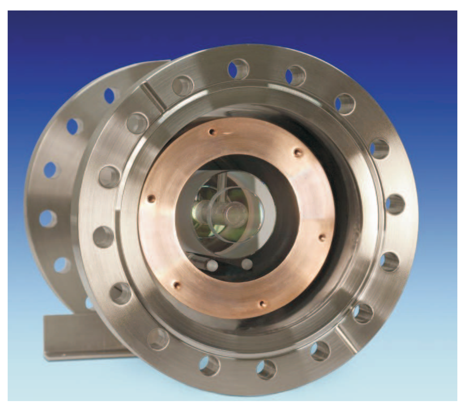
Recent results:

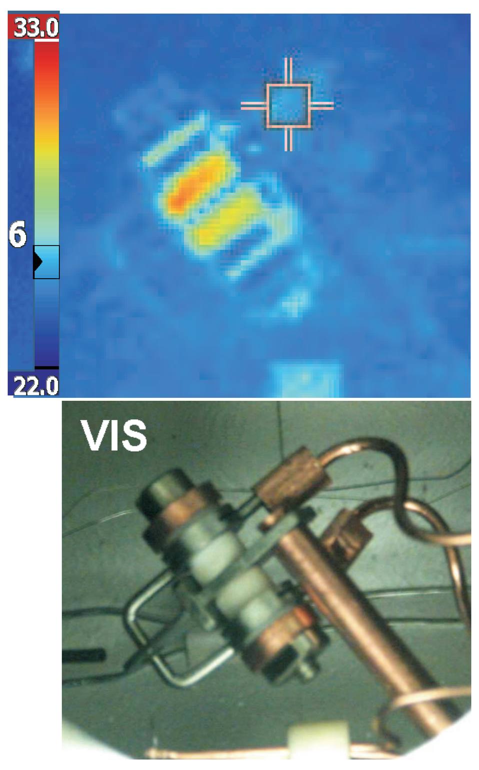
- investigation of magnitude and long-term variation of the stray-field induced quadrupole shift [2]
- systematic frequency uncertainty: $5 \cdot 10^{-16}$
- 90 h continuous frequency measurement vs. CSF1 $\Rightarrow$ $5 \cdot 10^{-16}$ statistical uncertainty

[1] I. Sherstov et al., PRA 81, 021805(R) (2010)
[2] Chr. Tamm et al., PRA 80, 043403 (2009)


RF Paul trap, ring diameter 1.3 mm


Endcap trap, inner cap diameter 0.99 mm

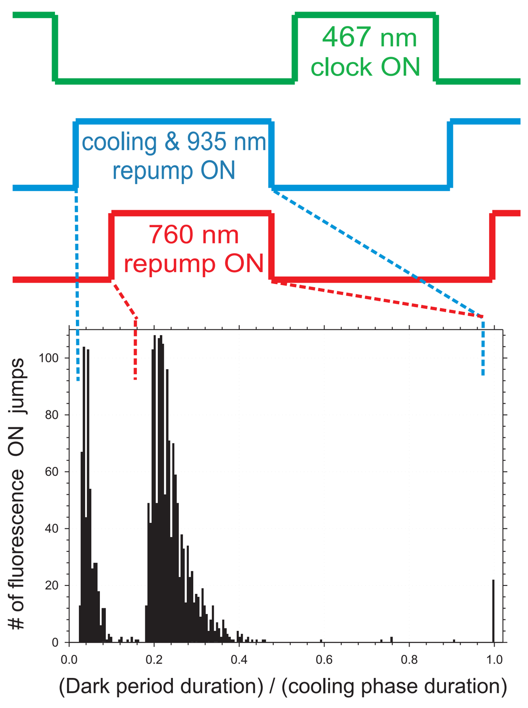

934 nm ULE reference cavity mount



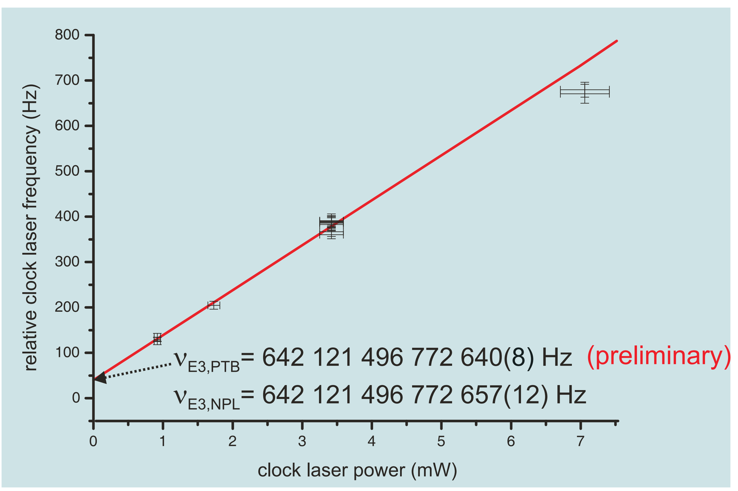
Thermal image of trap, camera range 7...14 μm

467 nm E3 transition

760 nm repumping efficiency

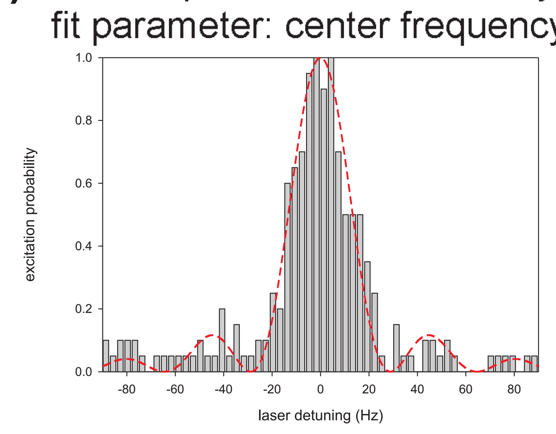


Extrapolation to zero light shift

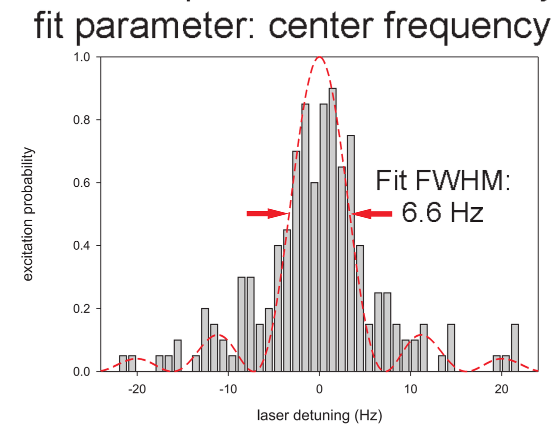


Spectroscopy of octupole transition

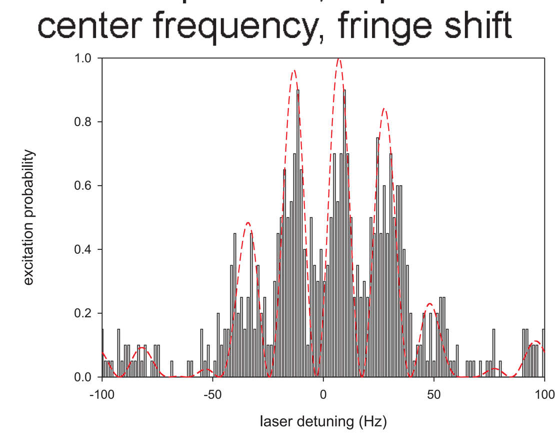
(a) 30 ms π-pulse excitation, 20 cycles/step, fit parameter: center frequency



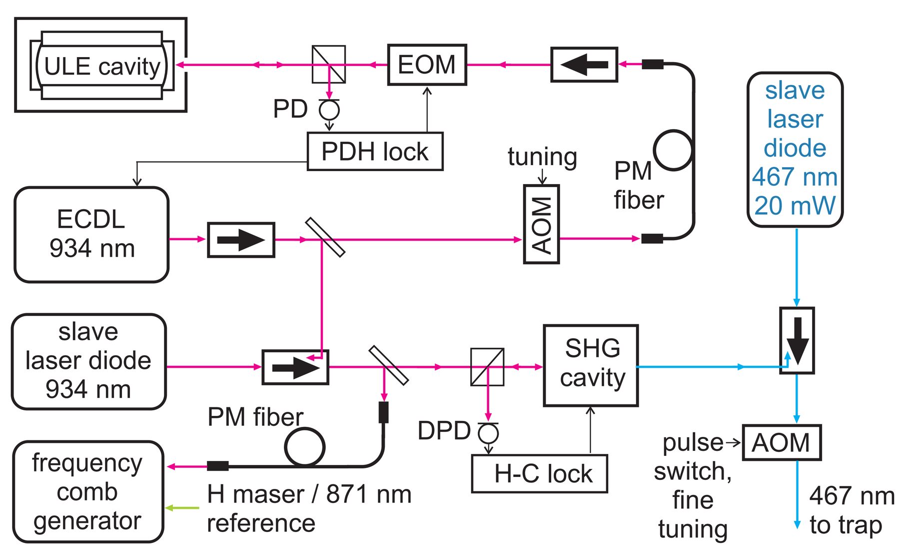
(b) 120 ms π-pulse excitation, 20 cycles/step, fit parameter: center frequency



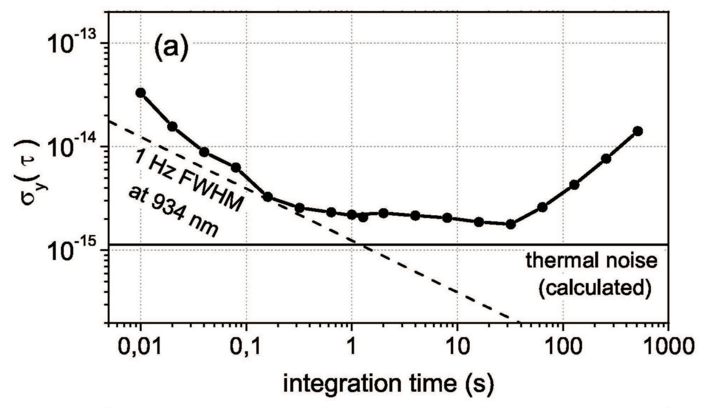
(c) Ramsey excitation, 15 ms pulses, 30 ms separation, fit parameters: center frequency, fringe shift

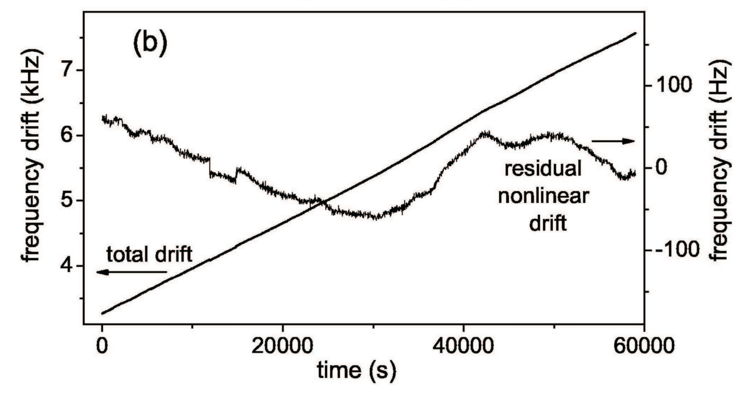


Clock laser setup



Clock laser stability & drift

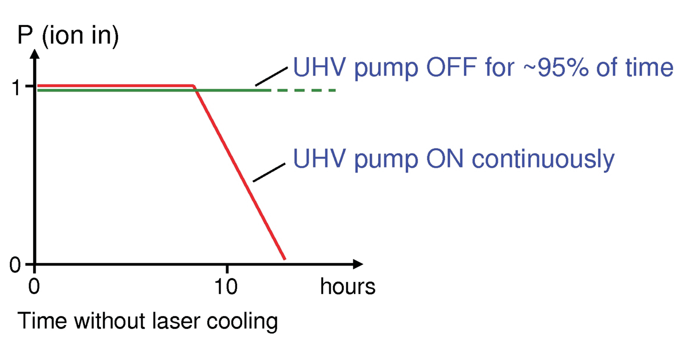




436 nm E2 transition & long-time storage

Ion storage time, collisions, YbH^+ photodissociation

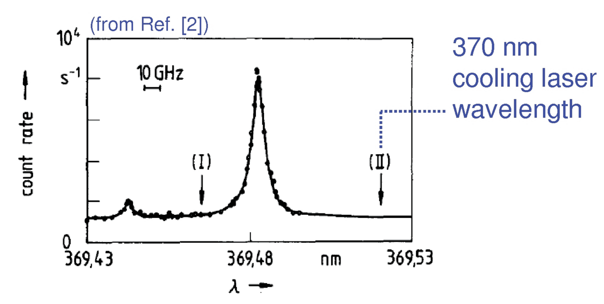
Observed in 2007/2008: (Paul trap, single $^{171}Yb^+$ ion, no laser cooling)



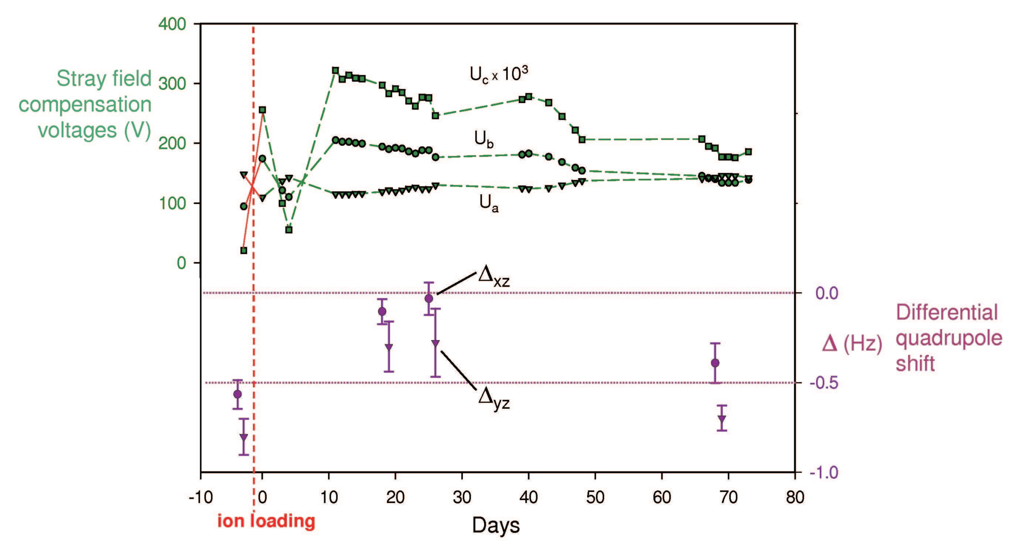
Presumed explanation: collisional cooling by background gas (~10^{-7}..10^{-6} mbar). YbH^+ formation?

Photodissociation resonances of YbH^+ [1,2]:

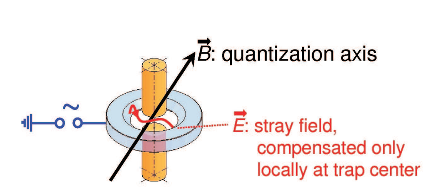
[1] K. Sugiyama, J. Yoda, Phys. Rev. A 55, R10 (1997)
[2] A. Bauch, D. Schnier, Chr. Tamm, J. Mod. Opt. 39, 389 (1992)



Variation of quadrupole shift and of compensation voltages



Quadrupole shift measurement scheme



$H_Q = (\nabla \vec{E})^{(2)} \cdot \Theta^{(2)}$

atomic quadrupole moment: $\Theta(Yb^+, {}^2D_{3/2}) = 9.75 \cdot 10^{-40}$ C·m²

"Itano theorem": $\nu_{Q,x} + \nu_{Q,y} + \nu_{Q,z} = 0$, with quadrupole shifts $\nu_{Q,i} := \nu_Q(\vec{B} \parallel \vec{e}_i)$, $i = x,y,z$

Quadrupole shift measurement using a differential servo scheme:

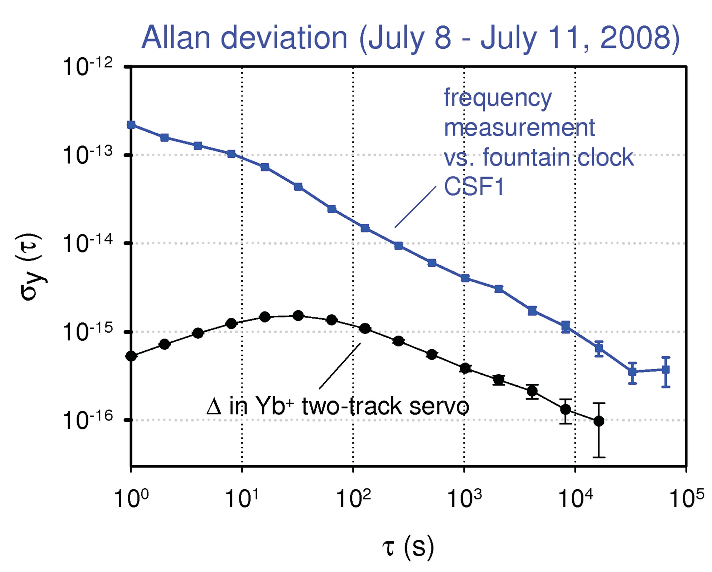
measure $\Delta_{xz} = \nu_{Q,x} - \nu_{Q,z}$ and $\Delta_{yz} = \nu_{Q,y} - \nu_{Q,z}$

$\Rightarrow$ $\nu_{Q,z} = -(\Delta_{xz} + \Delta_{yz})/3$

$\nu_{Q,x} = (2\Delta_{xz} - \Delta_{yz})/3$

$\nu_{Q,y} = (2\Delta_{yz} - \Delta_{xz})/3$

Instability at long averaging times



Systematic uncertainty estimate (2008 measurements)

$\nu(Yb^+$ E2$)$ = 688 358 979 309 306.62(73) Hz

	correction	uncertainty (Hz)
second-order Zeeman shift	-1.13	0.05
quadrupole shift and tensorial Stark shift	-0.36 to -0.19	0.2
scalar ac Stark shift	0	0.2
servo error	0	0.1
total	-1.43 to -1.26	0.31

Measurements performed at T = 300 K, not corrected for expected Blackbody shift of -0.35(7) Hz.

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