

# Spectroscopy of the $^2S_{1/2}(F=0) - ^2D_{3/2}(F=2)$ Clock Transition in Single $^{171}\text{Yb}$ Ions Towards Search for Temporal Variation of the Fine Structure Constant

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## Introduction

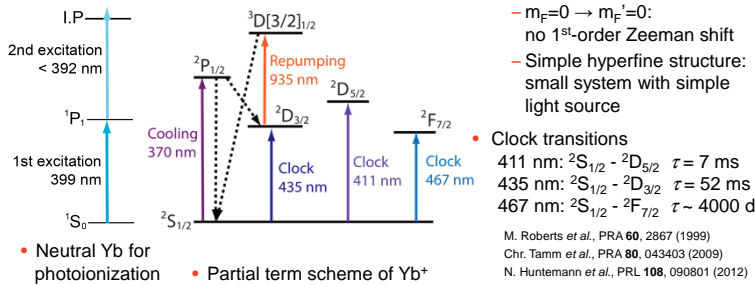
- Goal  
Realization of optical frequency standard with Yb ion  
→ Search for temporal variation of fine structure constant  $\alpha$

## Current work

Single  $^{171}\text{Yb}^+$  spectroscopy of  $^2S_{1/2} - ^2D_{3/2}$  clock transition

Y. Imai et al., ECTI2014: 3rd European Conference on Trapped Ions (2014)

## Ytterbium ion

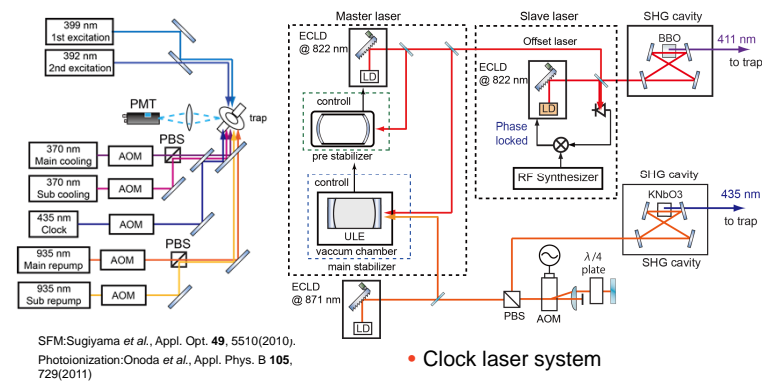


## Search for temporal variation of $\alpha$ with frequency ratio measurement

- Temporal variation in frequency ratio  $f_{E1}/f_{E2}$   
$$\frac{\partial \ln(f_{E1}/f_{E2})}{\partial t} = (A_{E1} - A_{E2}) \frac{\partial \ln \alpha}{\partial t}$$
  
Peik et al., Phys. Rev. Lett., **93**, 170801 (2004).  
 $f_E$ : Frequency of electric transition  
 $A$ : Sensitivity to time variation of  $\alpha$ , transition dependent  
 $R_{\alpha c}$ : Same in all transitions
- Frequency ratio measurement on three transitions in  $\text{Yb}^+$   
✓ Measurement in a single same ion: benefit in evaluation of uncertainties  
✓ Ratio measurement among three
- $^2S_{1/2} - ^2F_{7/2}$  vs  $^2S_{1/2} - ^2D_{3/2}$ : Detect temporal variation of  $\alpha$
- $^2S_{1/2} - ^2D_{3/2}$  vs  $^2S_{1/2} - ^2D_{5/2}$ : Check of possible other variants
- Current limit  
 $\text{Hg}^+/\text{Al}^+$  (NIST)  
 $(1.6 \pm 2.3) \times 10^{-17}/\text{yr}$  Rosenband et al., Science **319**, 1808 (2008).  
 $\text{Yb}^+$  (PTB, NPL)  
 $(-0.7 \pm 2.1) \times 10^{-17}/\text{yr}$  R. M. Godun et al., Phys. Rev. Lett. **113**, 210801 (2014)  
 $(-2.0 \pm 2.0) \times 10^{-17}/\text{yr}$  N. Huntemann et al., Phys. Rev. Lett. **113**, 210802 (2014)

Ion	Transition	sensitivity A
Hg	$^2S_{1/2} - ^2D_{5/2}$	-3.19
Al	$^1S_0 - ^3P_0$	0.008
Yb	$^2S_{1/2} - ^2F_{7/2}$	-5.20
	$^2S_{1/2} - ^2D_{3/2}$	0.88
	$^2S_{1/2} - ^2D_{5/2}$	0.88

## Laser system for the clock transitions in $\text{Yb}^+$



## Setup for Spectroscopy

822 nm: linewidth ~500 Hz evaluated by independent two setups  
871 nm: AR-coated chip, No pre-stabilizer

## Conclusion

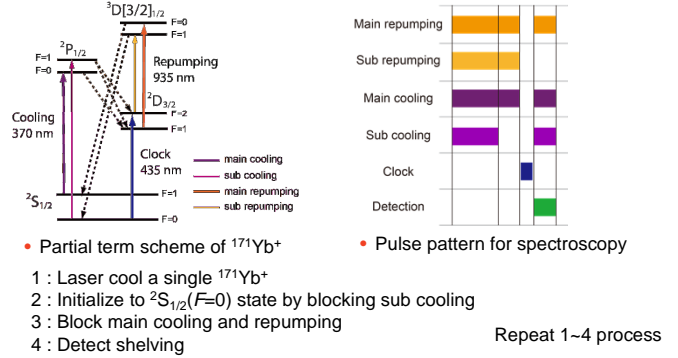
We are developing...

- single  $^{171}\text{Yb}^+$  spectroscopy of the  $^2S_{1/2} - ^2D_{3/2}$  clock transition  
- Motional sidebands of the  $m_F = 0 - m_{F'} = 0$  component are resolved  
- Current spectral width is 380 Hz

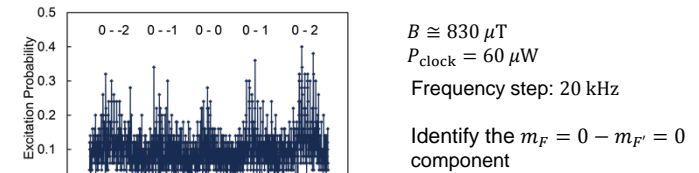
## Experiment

### Spectroscopy of the $^2S_{1/2} - ^2D_{3/2}$ clock transition in $^{171}\text{Yb}^+$

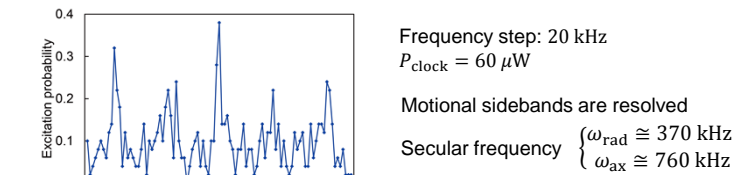
#### Process for spectroscopy



#### Spectrum of the $^2S_{1/2} - ^2D_{3/2}$ clock transition

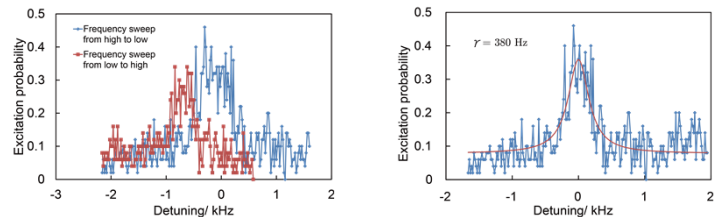


#### Zeeman components of $^2S_{1/2}(F=0) - ^2D_{3/2}(F=2)$ transition in single $^{171}\text{Yb}^+$

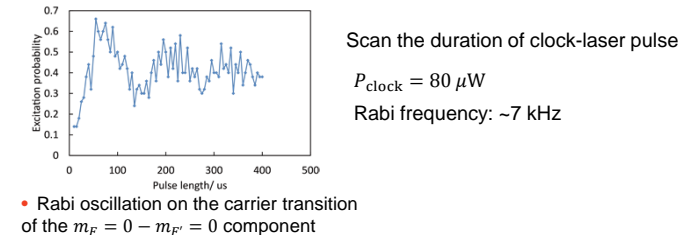


#### Spectrum of the $m_F = 0 - m_{F'} = 0$ component

#### High-resolution scanning of the carrier spectrum in the $m_F = 0 - m_{F'} = 0$ component



#### Fit the two spectra → correction of a linear frequency drift



## Next task

- Improving linewidth of the clock laser
- Construction of the optical clocks referenced to the  $^2S_{1/2} - ^2D_{3/2}$  and the  $^2S_{1/2} - ^2D_{5/2}$  clock transitions and evaluation of their uncertainties of the clocks