Spectroscopy of the $^2S_{1/2}$ - $^2D_{5/2}$ clock transition in single $^{138}Ba^+$ ions

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Introduction

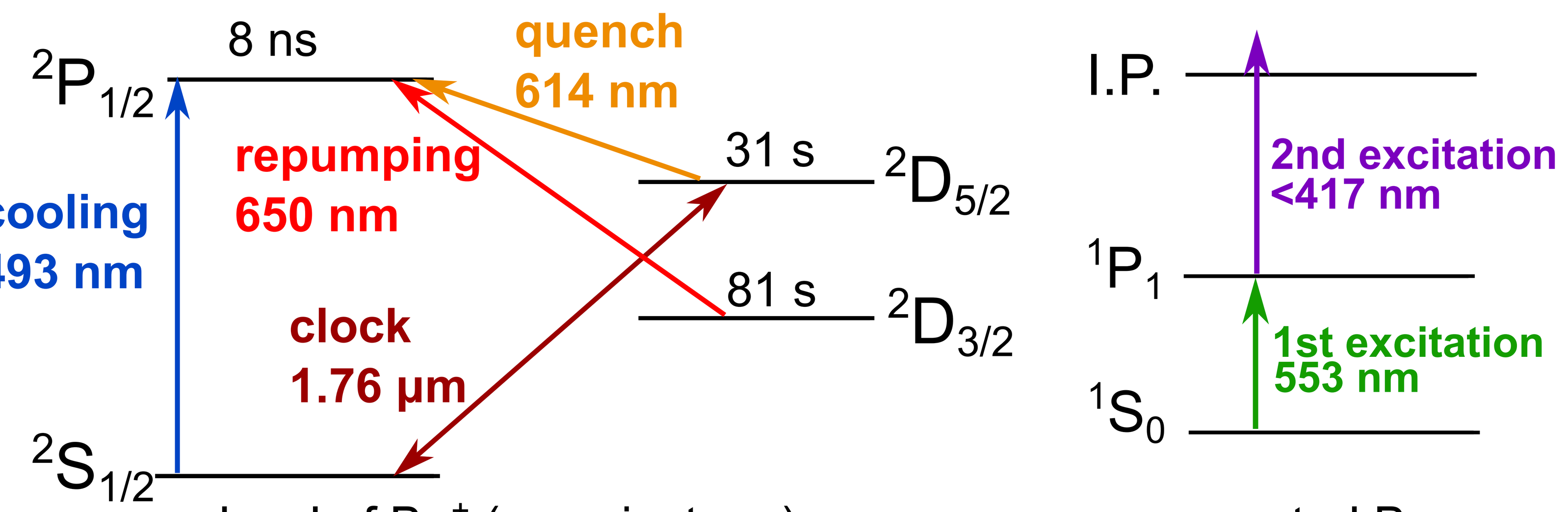
- Goal
  Realization of optical frequency standard with Barium ion
- Current work
  - Linenarrowing of the light sources for clock transition $^2S_{1/2}$ - $^2D_{5/2}$
  - Spectroscopy of the $^2S_{1/2}$ - $^2D_{5/2}$ in single $^{138}Ba^+$ ions

Ba ion

- Clock transitions
  $^2S_{1/2}$ - $^2D_{5/2}$ [1-3]: 1.76 μm $\tau = 31$ s
  $^2S_{1/2}$ - $^2D_{3/2}$ [4] : 2.05 μm $\tau = 81$ s

[1]N. Kurz, *et al.*, *Phys. Rev. A*, **82,** 030501(R) (2010)
[2]W. Nagourney, *et al.*, *Opt. Commun.*, **79**, 176 (1990)
[3]B. Appasamy, *et al.*, *Appl. Phys. B*, **60**, 473 (1995)
[4]A. Kleczewski, *et al.*, *Phys. Rev. A*, **85** 043418 (2012)

- Odd isotope(135, 137)
  $^2S_{1/2}(F=2, m_F=0)$ - $^2D_{3/2}(F=0, m_F=0)$
  - small 1st-order Zeeman shift
  - Insensitive to quadrupole electric field



enegy level of Ba^+ (even isotope) neutral Ba

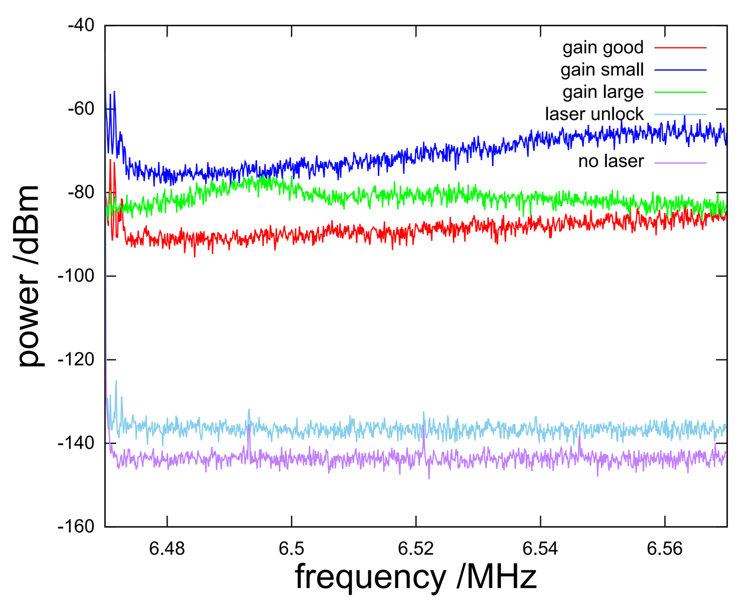
This work

- linenarrowing of 881 nm-ECDL
- phase locking of 1.76 μm-ECDL to 881 nm-ECDL
- observation of quantum jumps

Experiment

Linenarrowing of 881 nm-ECDL

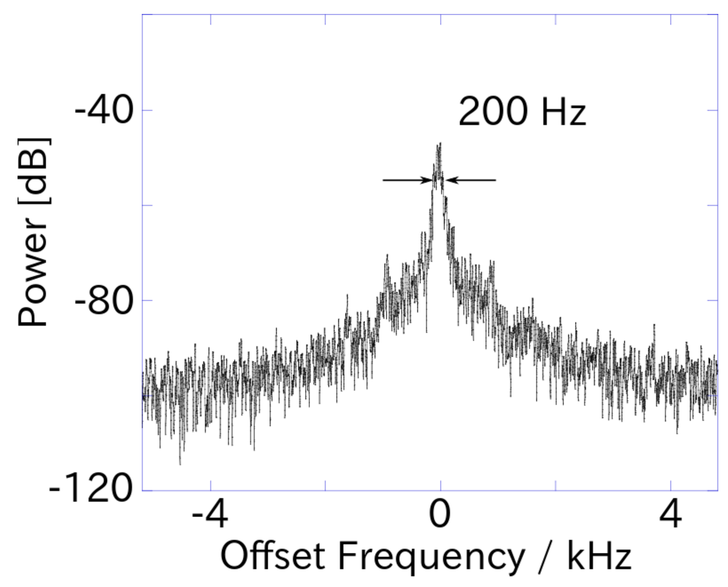
- modulation frequency: 6.47 MHz
- cavity linewidth: ~ 52 kHz



spectrum of signal reflected from the cavity

- relative linewidth:
  7.2 Hz to cavity resonance

- beatnote between 881 nm-ECDL and optical frequency comb stabilized to other linenarrowed laser

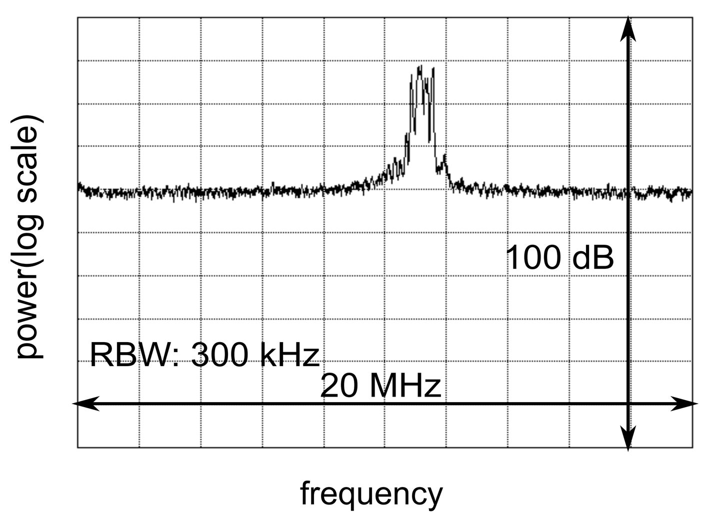


beatnote of 881nm-ECDL

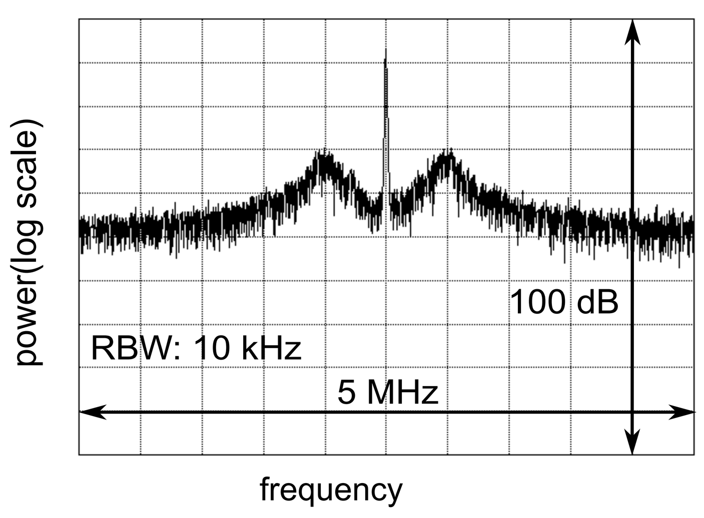
- linewidth: < 200 Hz

Phase locking of 1.76 μm-ECDL

- power
  881 nm: 500 μW SHG of 1.7 μm: 100 nW
- S/N of beat signal: ~ 29 dB @RBW: 300 kHz



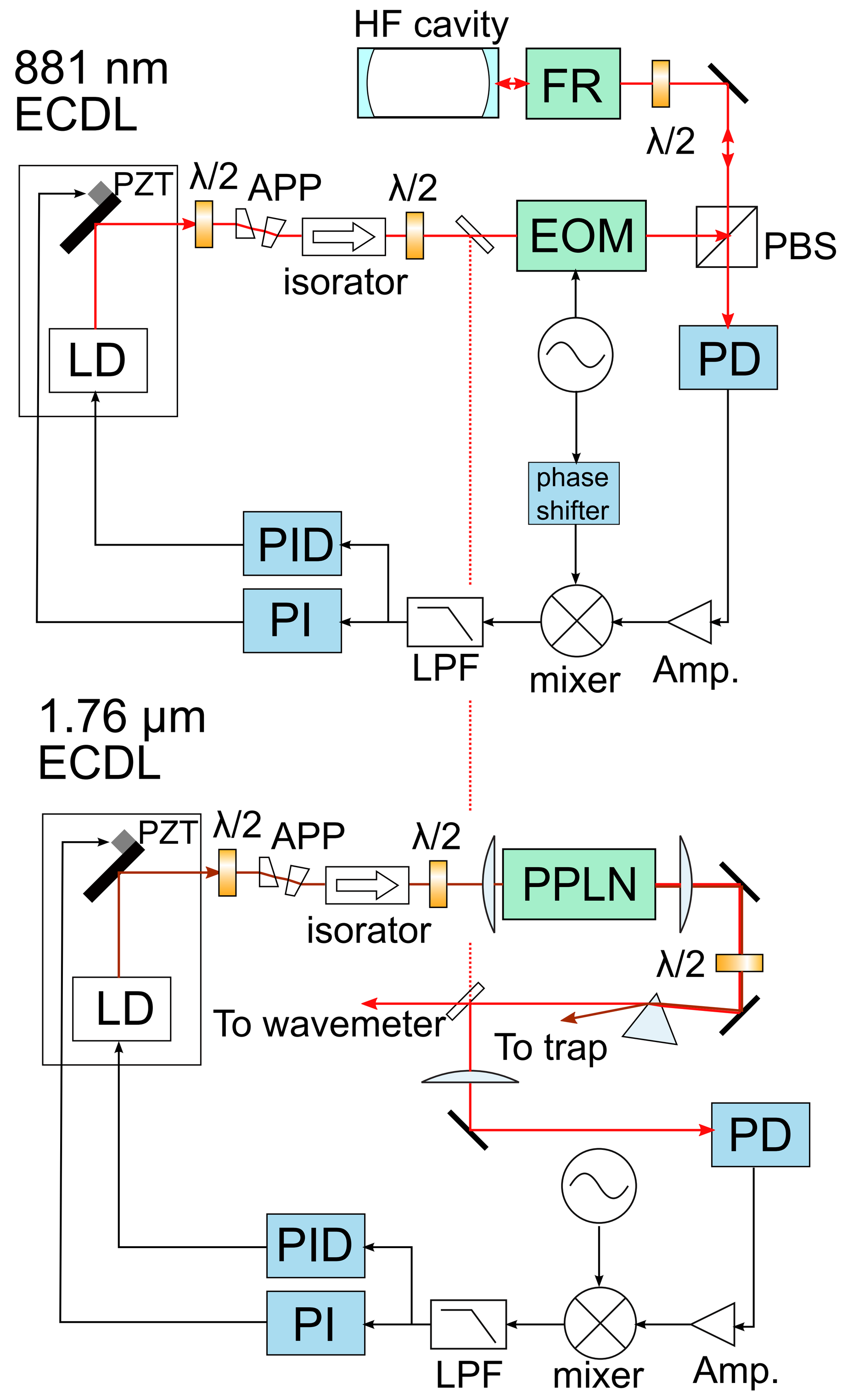
beat signal (unlocked)



beat signal (locked)

Setup

System of clock laser for $^2S_{1/2}$ - $^2D_{5/2}$

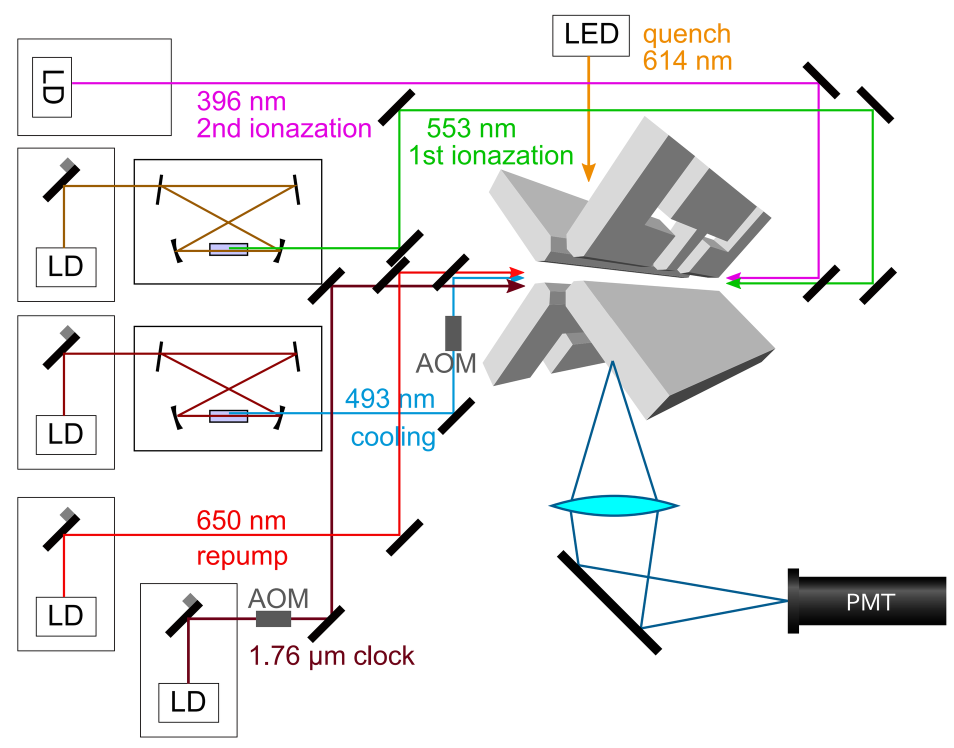


- 881 nm-ECDL
  power: 31 mW
- finesse ~ 29000
- linenarrowing of 881 nm-ECDL by FM sideband method [5]
- feedback to PZT and injection current of LD

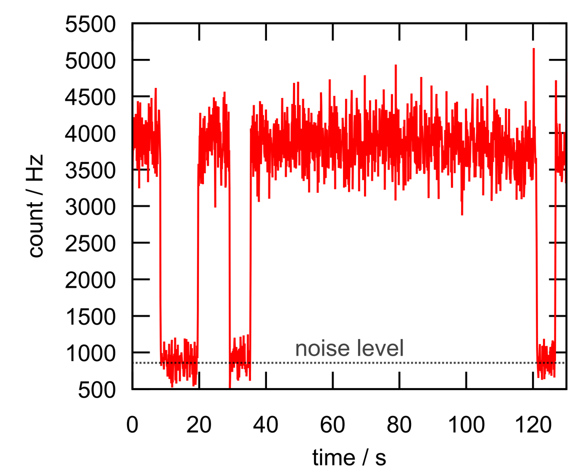
[5]R. W. P. Drever, *et.al.*, *Appl. Phys. B*,**31,** 97(1983)

- 1.76 μm-ECDL
  power: ~ 20 mW
- SHG
  - periodically poled lithium niobate(PPLN)
  - phase-matching temp: ~ 170 deg
  - power: ~ 250 nW
- detection of the beat between 881 nm-ECDL and second harmonic of 1.76 μm-ECDL
- feedback to PZT and injection current of LD

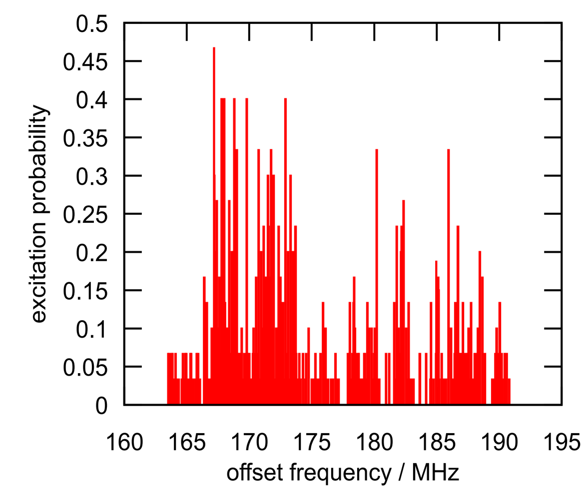
Observation of quantum jumps



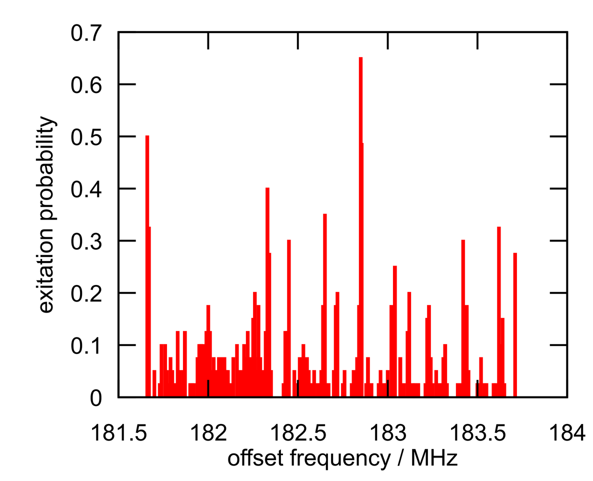
- cooling laser:
  SHG of 986 nm-ECDL
- repumping laser:
  650 nm-ECDL
  - stabilized using I_2 absorption signal
- 1st ionization laser:
  SHG of 1107 nm-ECDL
- 2nd ionization laser:
  396 nm-LD
- quenching by LED
- detecting fluorescence by PMT



- quantum jumps of $^2S_{1/2}$ - $^2D_{5/2}$ clock transition
- S/N ~ 3000 / 800



- single-ion spectroscopy of Zeeman components(?)
  - frequency step : 25 kHz
  - power of clock laser : ~ 1 mW
  - probe time : 100 ms



- high resolution scanning motional sideband resolved
  - frequency step : 10 kHz
  - power of clock laser : ~ 1 mW
  - probe time : 50 ms

Conclusion

- Linenarrowing of 881 nm-ECDL: 200 Hz of linewidth
- Phase locking of 1.76 μm-ECDL to 881 nm-ECDL
- Spectroscopy of the $^2S_{1/2}$ - $^2D_{5/2}$ clock transition in single $^{138}Ba^+$ ions

Next work

- Identification of the Zeeman components
- Clear detection of motional sidebands