Ytterbium lattice clocks

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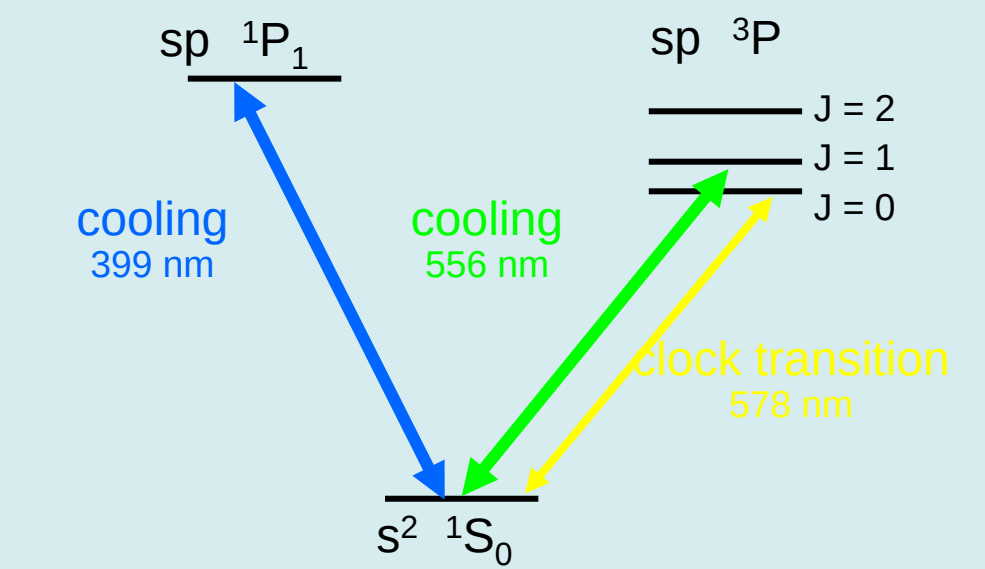
Ytterbium



Isotope	Relative atomic mass [amu]	Relative abundance [%]	Nuclear spin
^{174}Yb	173.938 8581(30)	31.83(92)	0
^{172}Yb	171.936 3777(30)	21.83(67)	0
^{173}Yb	172.938 2068(30)	16.13(27)	5/2
^{171}Yb	170.936 322(3)	14.28(57)	1/2
^{176}Yb	175.942 568(3)	12.76(41)	0
^{170}Yb	169.934 759(3)	3.04(15)	0
^{168}Yb	167.933 894(5)	0.13(1)	0

The Yb clock at NIST

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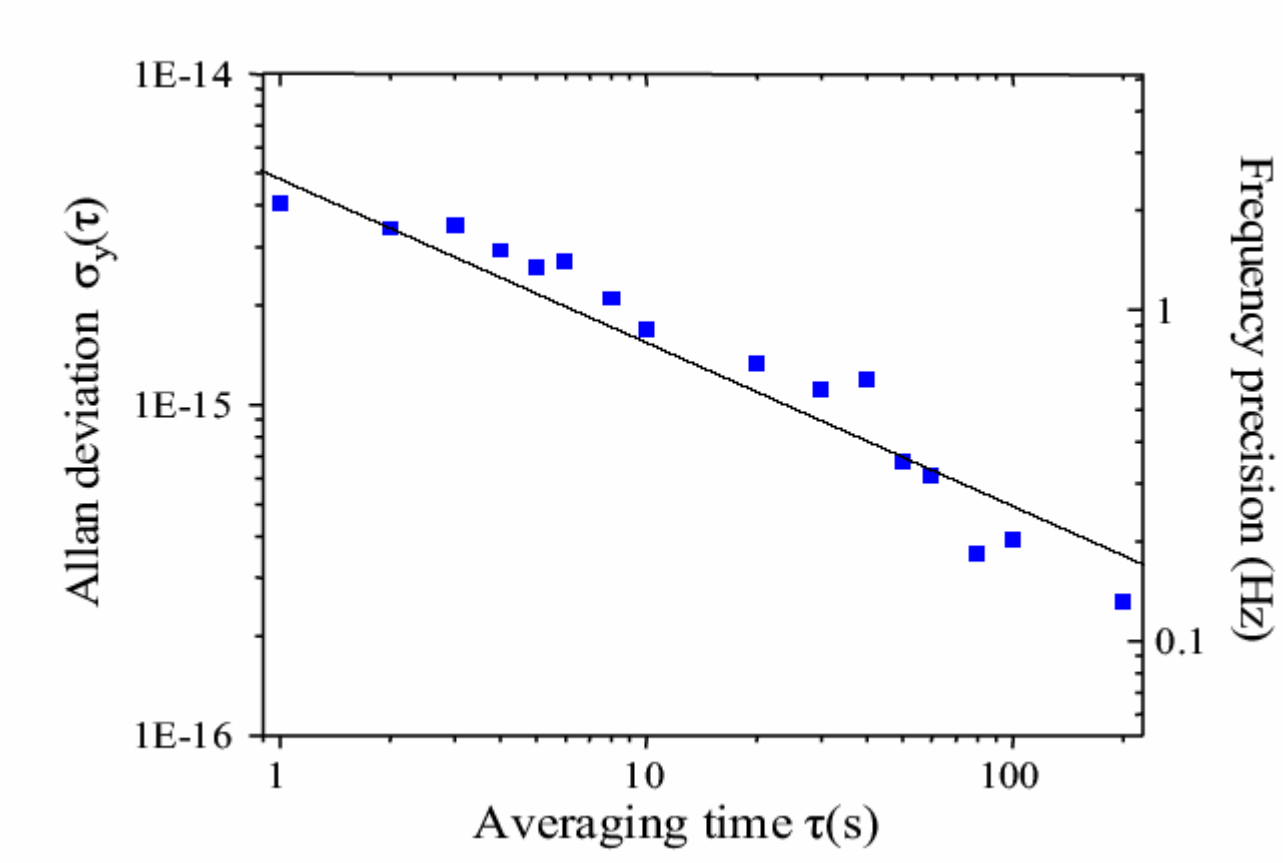
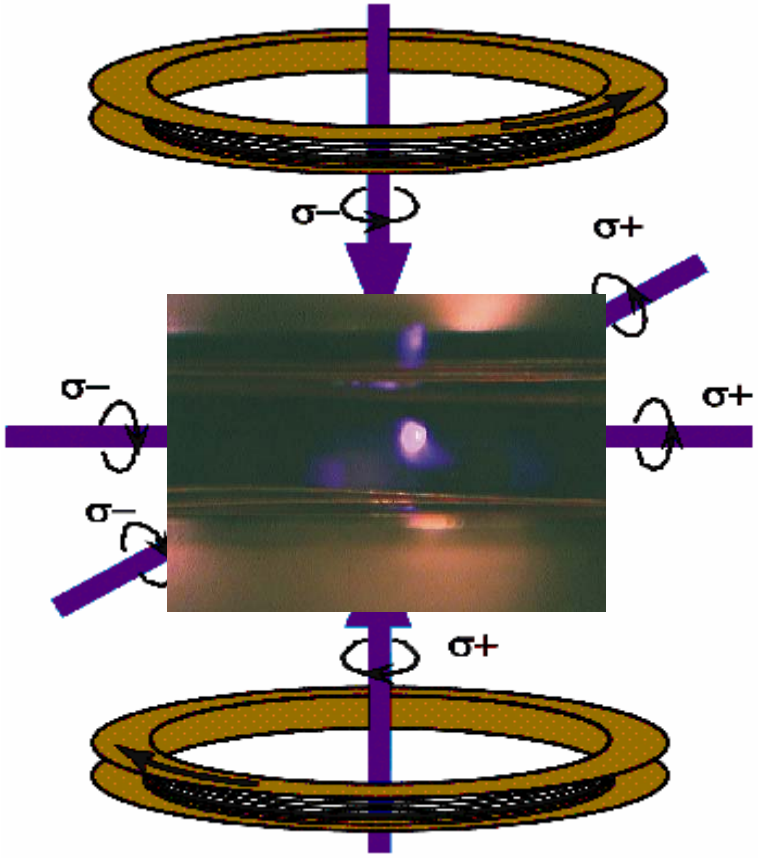
Allan deviation of beatnote between Ca and Yb clock:

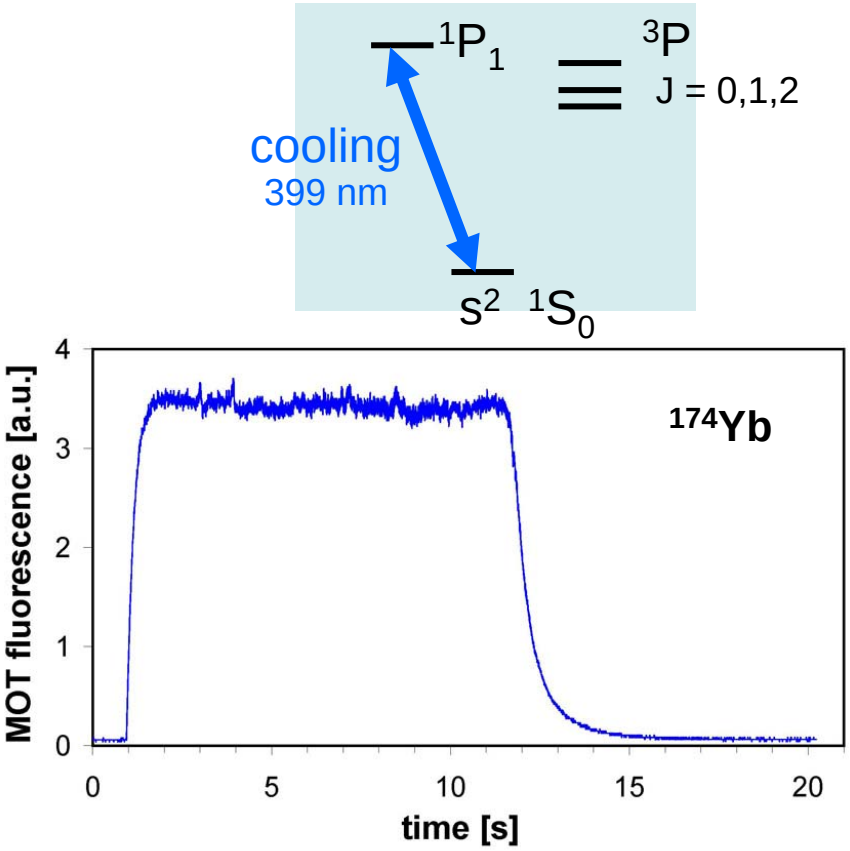


C. W. Oates et al., Proc. 2006 IEEE Intl. Freq. Cont. Symp., p. 74 (2006)

Precooling of Yb

Precooling with diode lasers @399 nm:



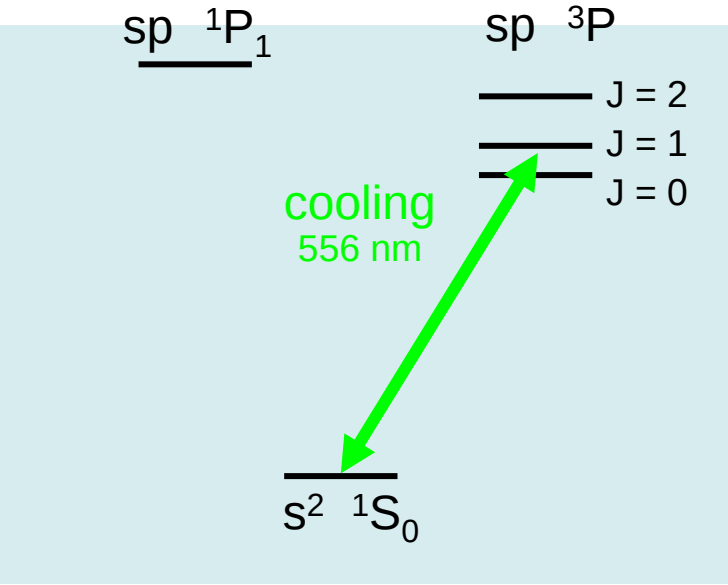


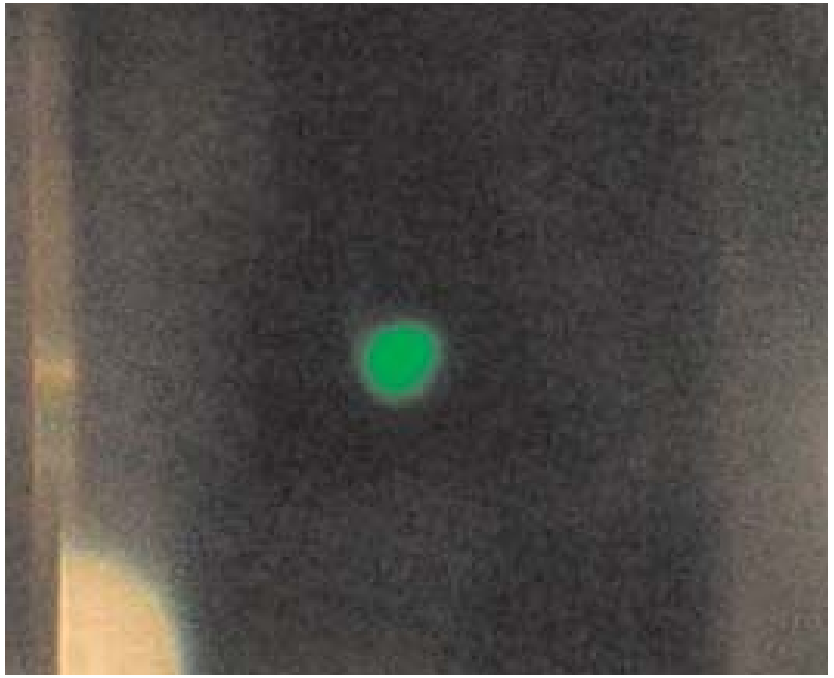
Required laser power:

- 5 mW for slower
- 10 mW for MOT

- 4 bosonic + 2 fermionic isotopes trapped
- more than 3 x 10^7 atoms for ^{174}Yb (< 200 ms)
- T (^{174}Yb) ~ 2 mK

Postcooling of Yb





Current laser system:

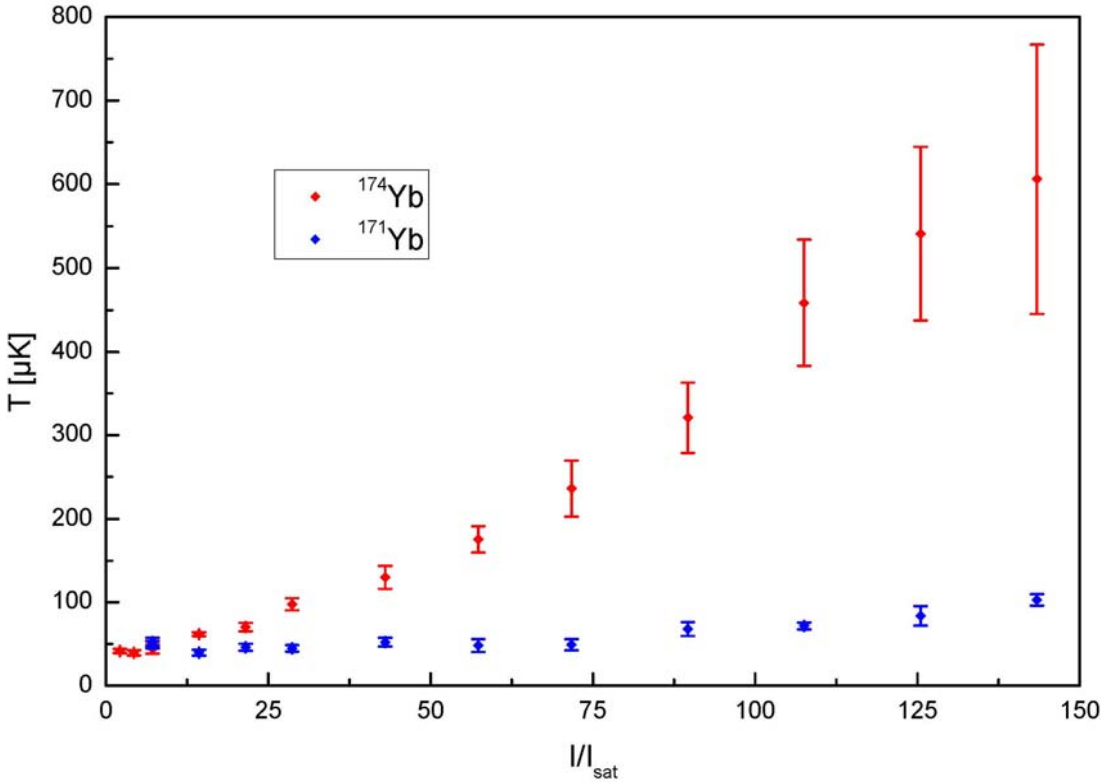
- dye laser (Rhodamin 110)
- 10 mW
- ~200 kHz linewidth

Future laser system:

- frequency doubled fiber or diode laser
- 1 W @ 1112 nm ï few 100 mW @ 556 nm
- 20 kHz linewidth

Postcooling of Yb

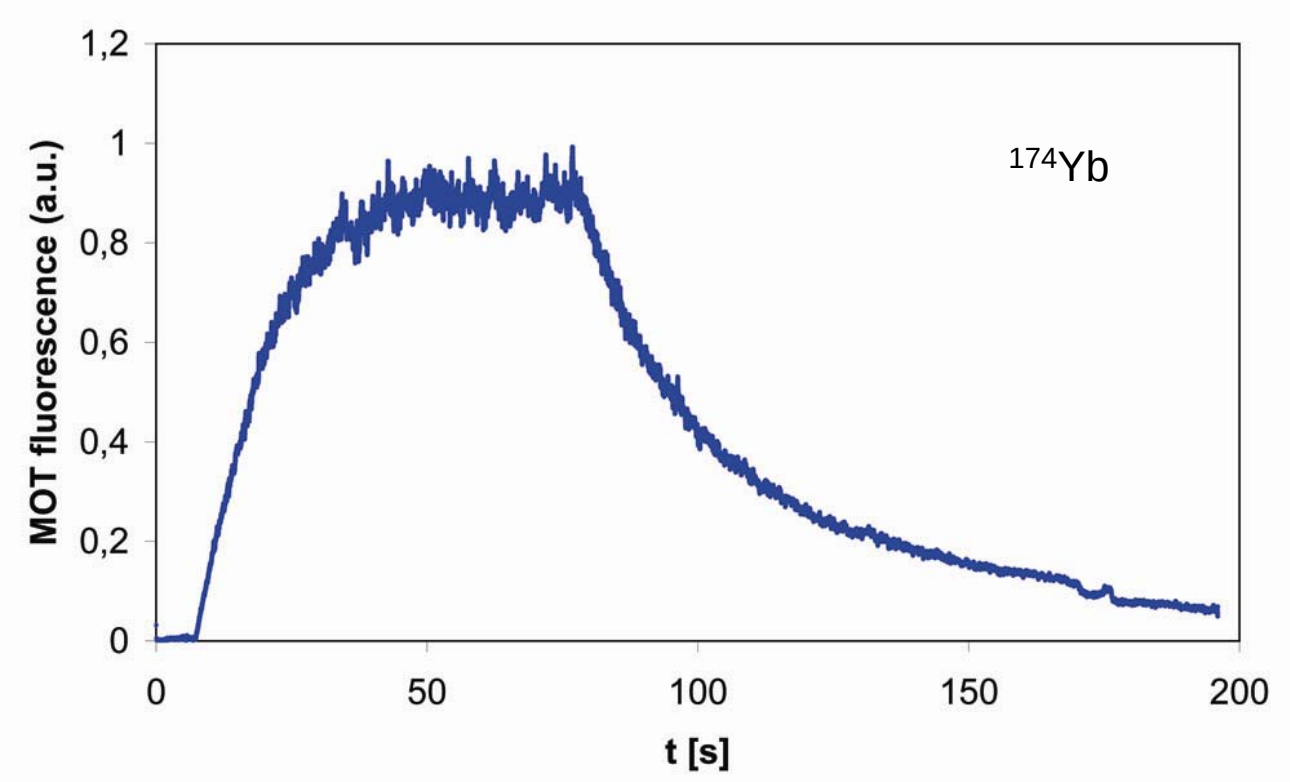
Cooling of fermionic and bosonic isotopes:



- T < 50 μK
- N(^{174}Yb) ~ 2 x 10^7 atoms
- N(^{171}Yb) ~ 10^7 atoms
- 10^{11} atoms/cm^{-3}
- cooling time 50 ms

Postcooling of Yb

Direct loading of postcooling MOT:

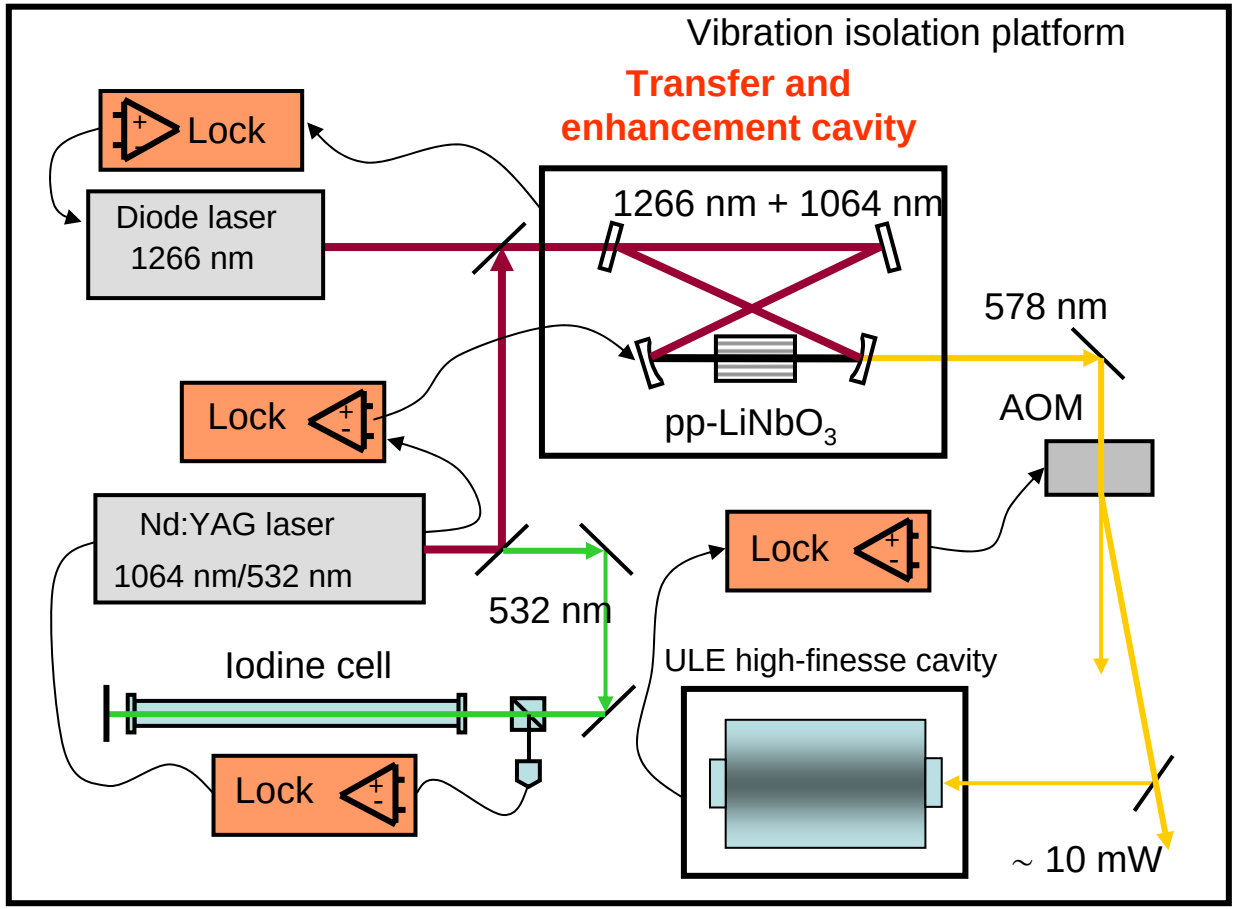


Intercombination MOT (556 nm) with 10 mW of power loaded from Zeeman slower

î only 1 magnetooptical trap required if sufficient laser power is available @ 556 nm

578 nm Yb clock laser

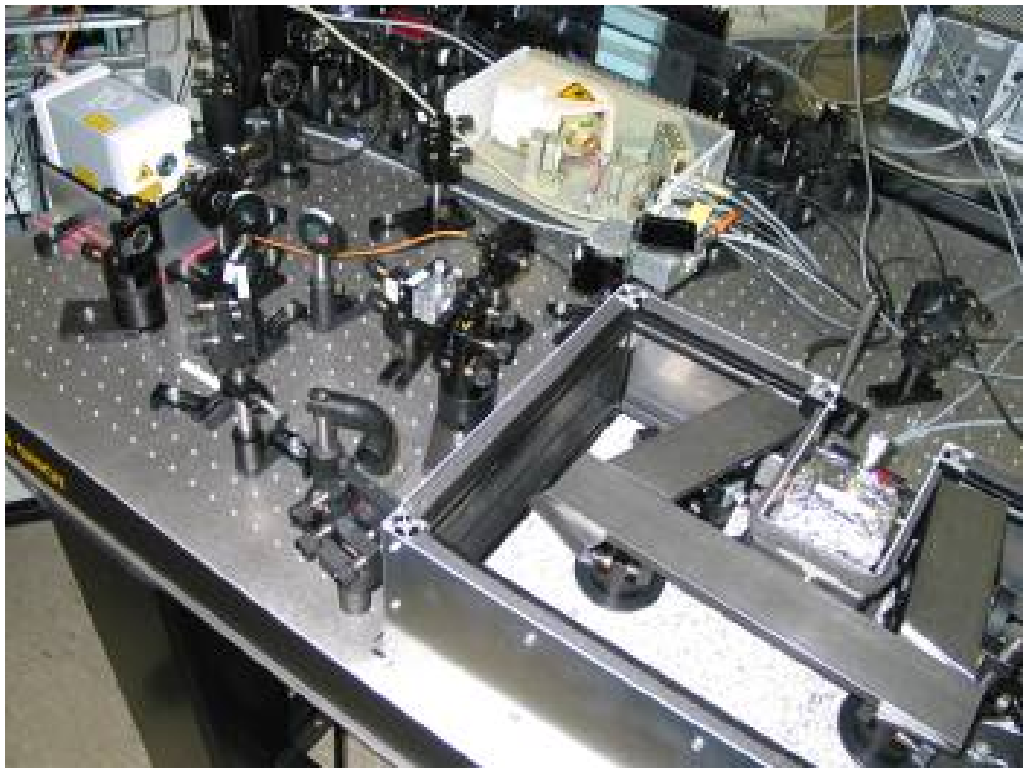
Current Setup at Düsseldorf



Diode laser: 20 mW @ 1266 nm

Nd:YAG laser: 250 mW @ 1064 nm

578 nm Yb clock laser

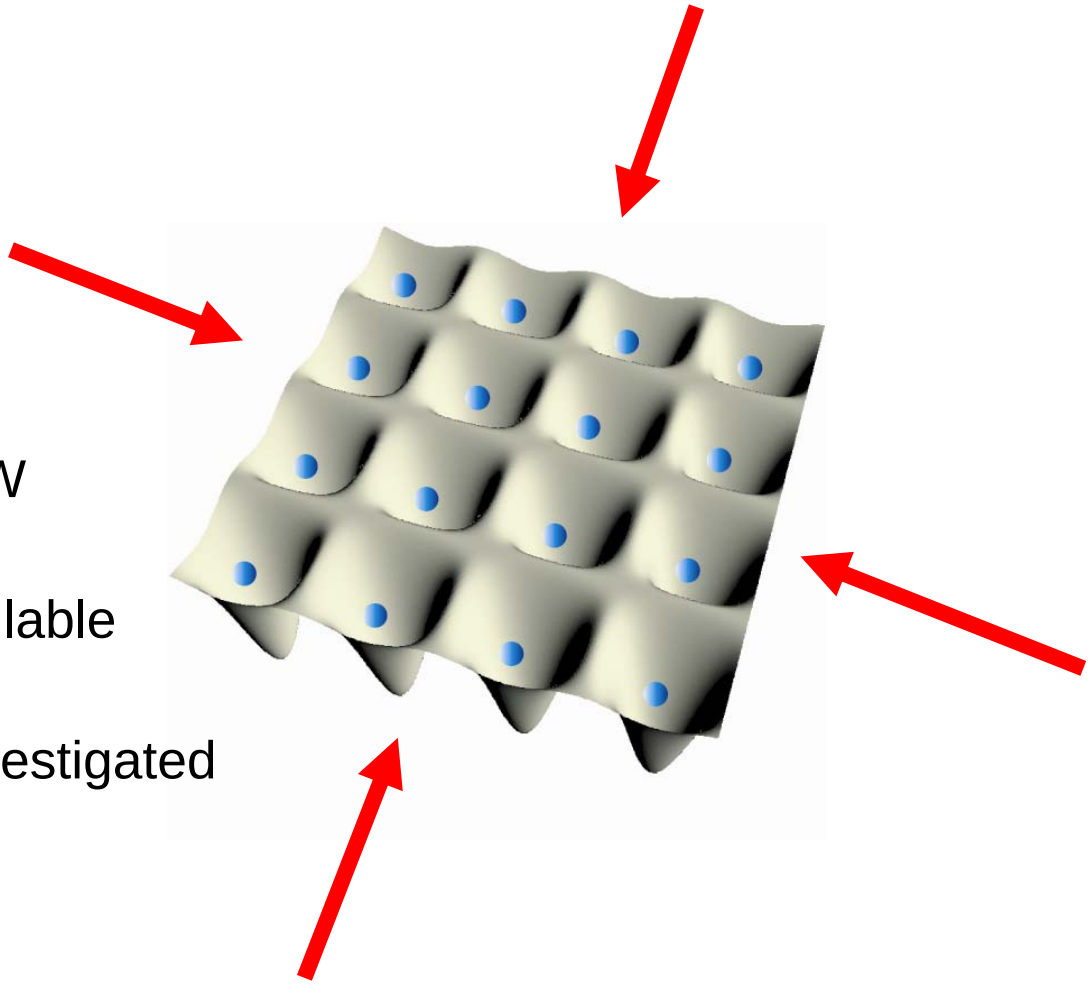


Possible simplifications:

- Frequency doubling of fiber laser or diode laser at 1156 nm
- Sum frequency generation of high power solid-state or fiber lasers

Yb lattice at the magic wavelength

- Magic wavelength: 759 nm
- Required power: approx. 1W
- Diode laser technology available
- Hyperpolarizability to be investigated



What could a space Yb clock look like?

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- UHV system with a dimension of 1 m x 0.5 m x0.5 m
- Zeeman slowing @ 399 nm (diode lasers)
- Direct loading of intercombination MOT @ 556 nm (frequency doubled fiber laser)
- Optical lattice at the magic wavelength using diode lasers
- Solid state or diode laser based clock laser @ 578 nm
- No additional repumping lasers required