Compact structures for single-beam magneto-optical trapping of ytterbium

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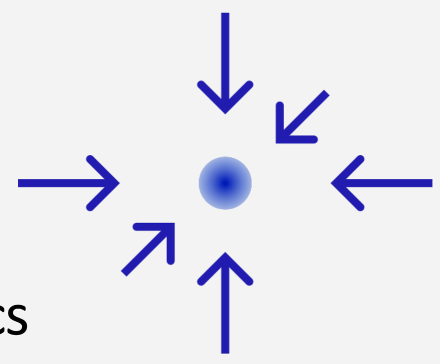
Motivation

Transportable clocks:
- Enable geopotential measurements, chronometric levelling
- Enable on-site clock comparisons
- Reduction of size, weight and power consumption of key subcomponents required

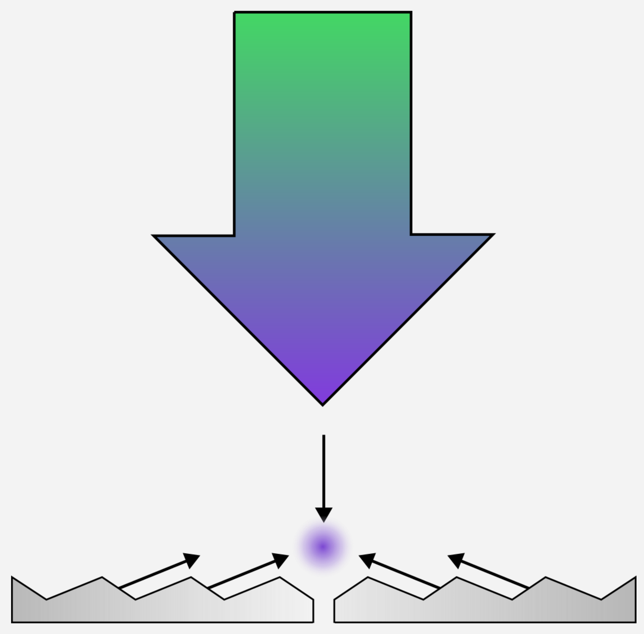
Six-beam MOT:
- Six laser beams from all directions
- Extensive optical setup, frequent realignment required
- Can be miniaturized by in-vacuum optics



Ytterbium:
- Employed in optical lattice clocks
- Convenient cooling transitions at 399 nm and 556 nm

Fresnel reflector

- Tetrahedral beam configuration
- Periodic mirror structure, inspired from Fresnel lenses
- Three-segmented copper structure, coated with aluminum → Achromatic
- Similar trapping dynamics as for grating MOTs



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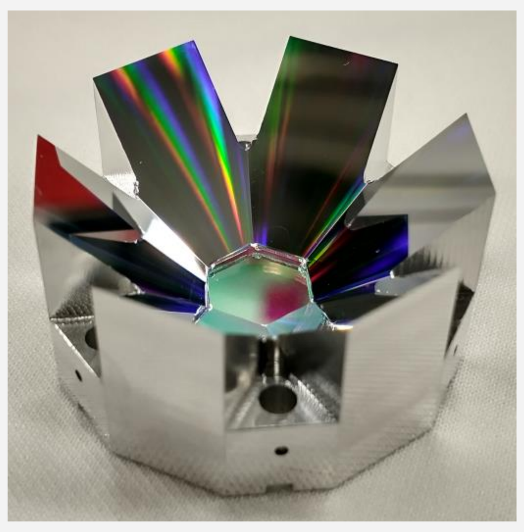
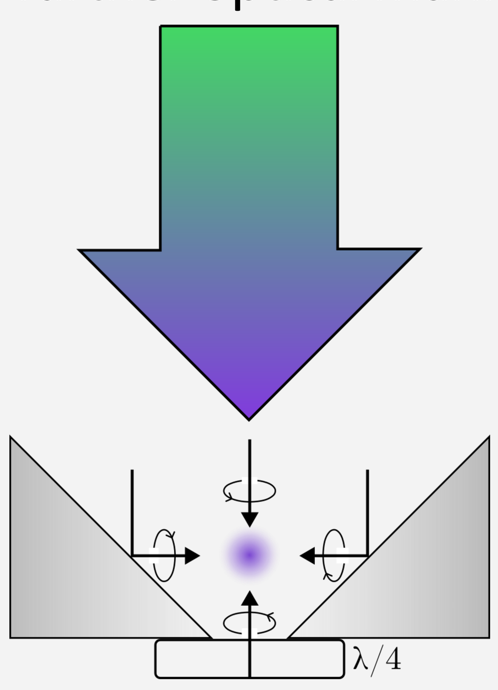
Pyramid reflector

- Monolithic aluminum structure
- Bichromatic waveplate for 399 nm and 556 nm instead of pyramid apex
- Generates conventional beam geometry
- Hexagonal symmetry → Radial access for loading and further optical manipulation





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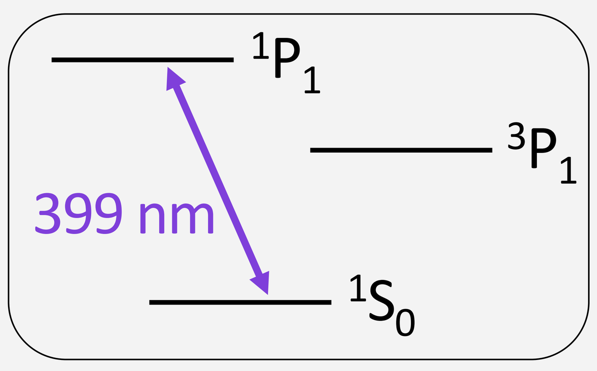
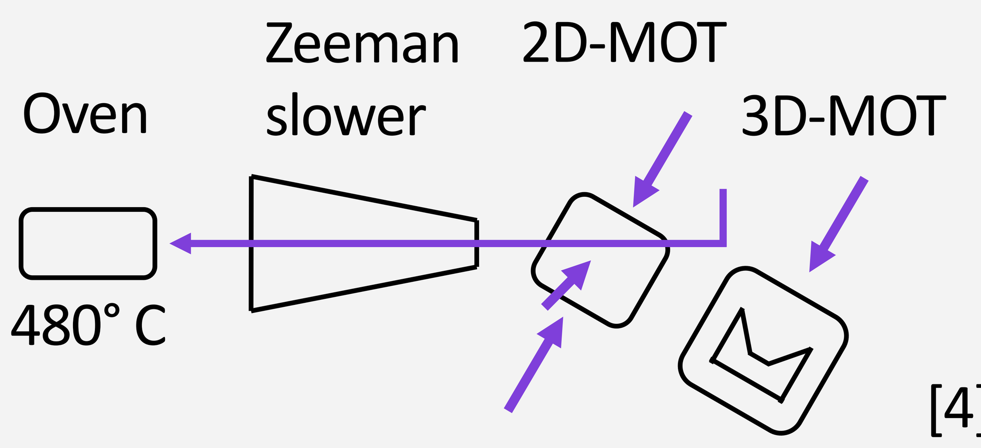
First-stage MOT



Atom source:



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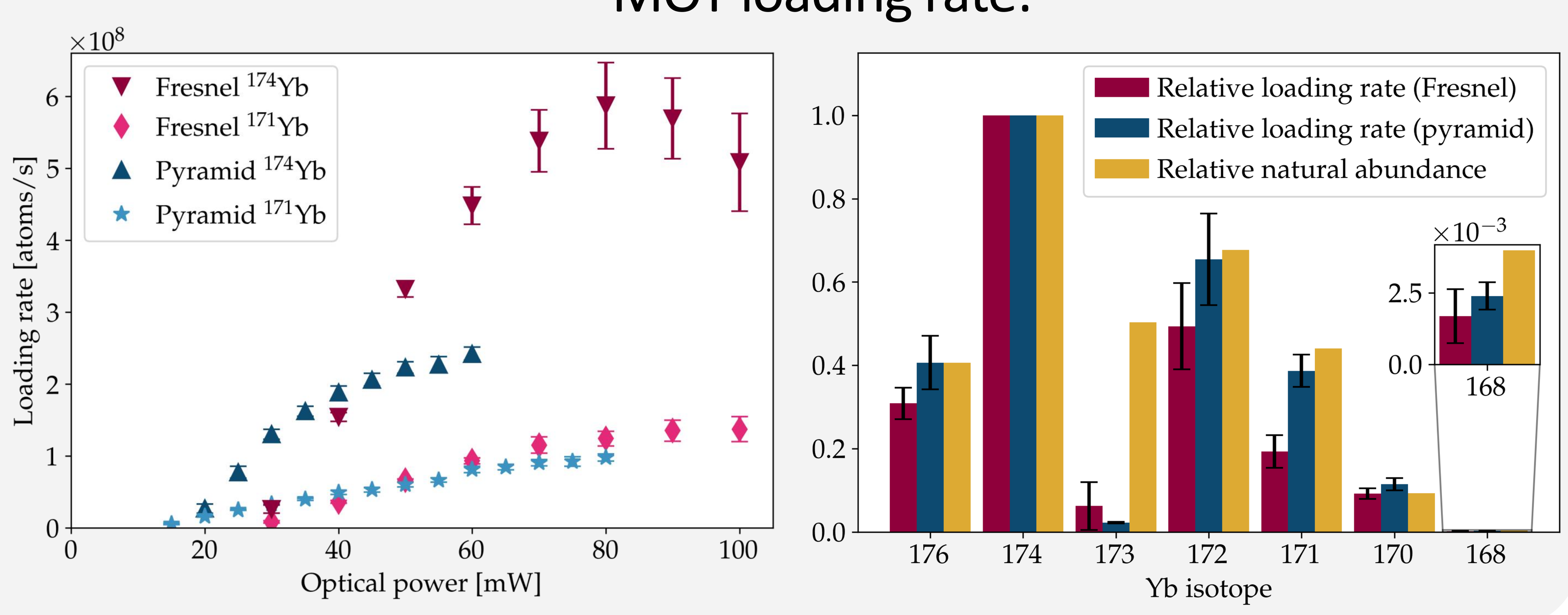
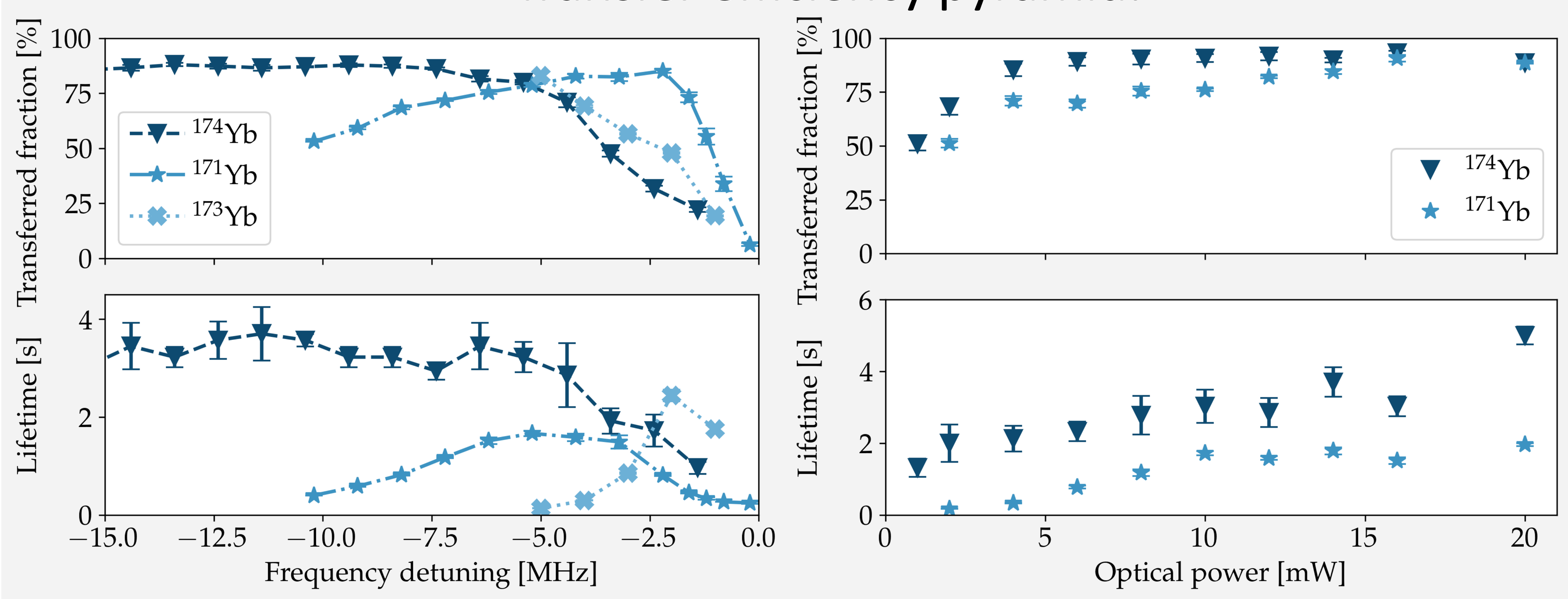
- Characterization of both reflectors with the same atom source, both loaded radially
- MOT loading rates above 10^8 at/s for bosonic ^{174}Yb and fermionic ^{171}Yb with both reflectors demonstrated
- Pyramid reflector more efficient at low optical input power
- Fresnel reflector more performant at higher input power
- All stable Yb isotopes were trapped successfully

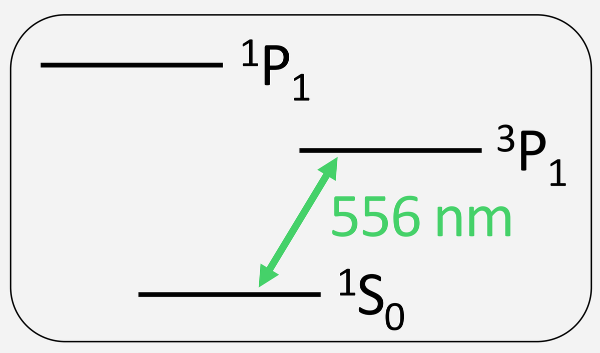
MOT loading rate:



Second-stage MOT

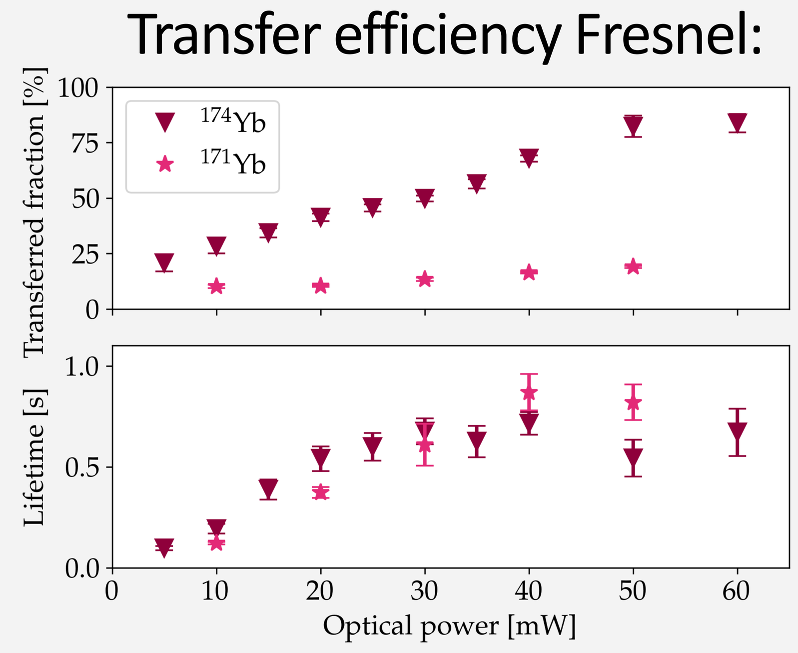
Transfer efficiency pyramid:





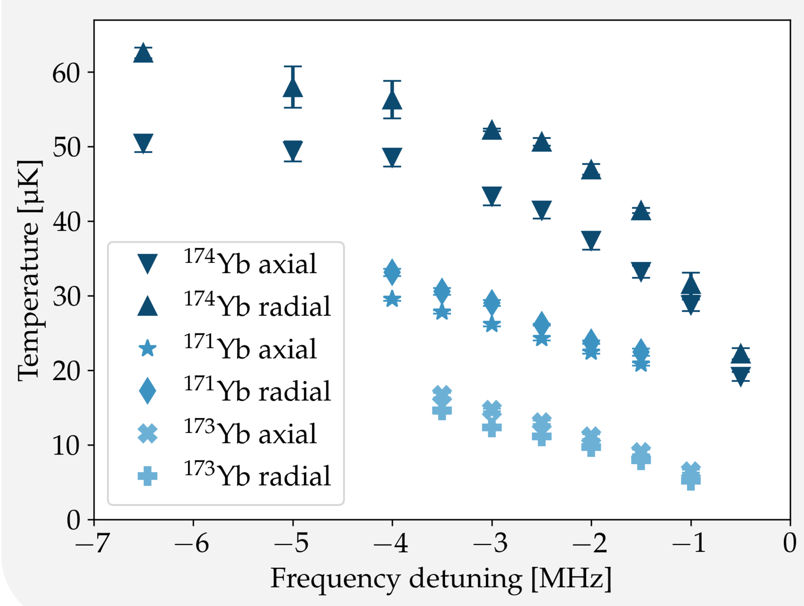
- 20 ms transfer time
- No frequency modulation of 556 nm laser required
- Transfer efficiency > 80% possible
- Final temperature 20 µK

Transfer efficiency Fresnel:

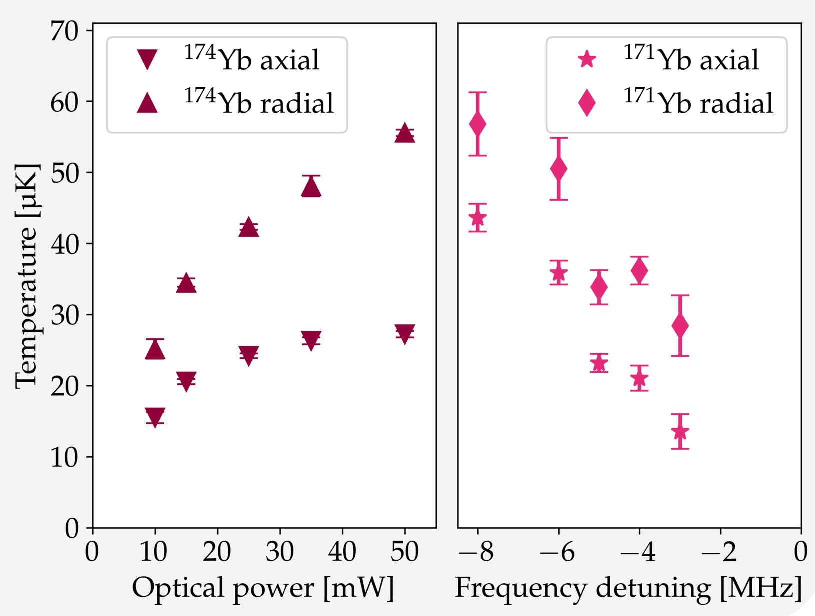


First demonstration of 2nd stage cooling of a fermionic alkaline-earth-like isotope in a non-conventional MOT geometry!

Temperature pyramid:



Temperature Fresnel:



References

Pick et al., arXiv:2403.07446 (2024) → Accepted for publication in Review of Scientific Instruments

[1] Bowden et al., Scientific Reports. 9, 11704 (2019)
[2] Bondza et al., Review of Scientific Instruments. 95 (2024)
[3] Bondza et al., Patent DE102020102222B4 (2022)
[4] Wodey et al., J. Phys. B: At. Mol. Opt. Phys. 54, 35301 (2021)

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