A new Na-K apparatus to study quantum thermodynamics

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KIRCHHOFF-INSTITUT FÜR PHYSIK

SynQS

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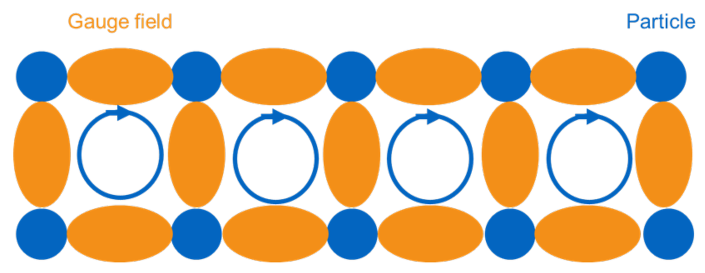
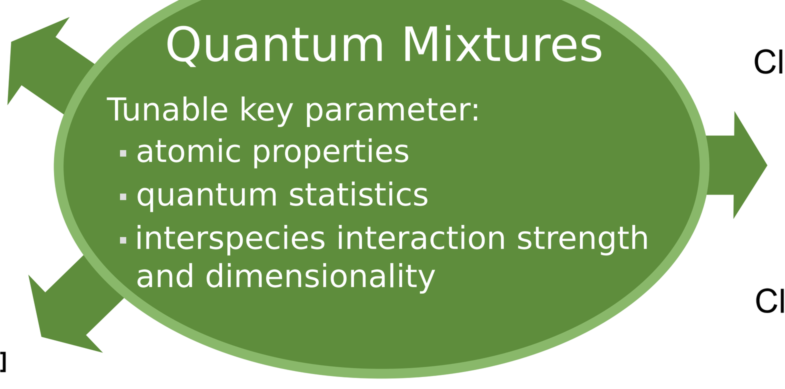
Why quantum mixtures?

Dynamical Gauge Fields [3]



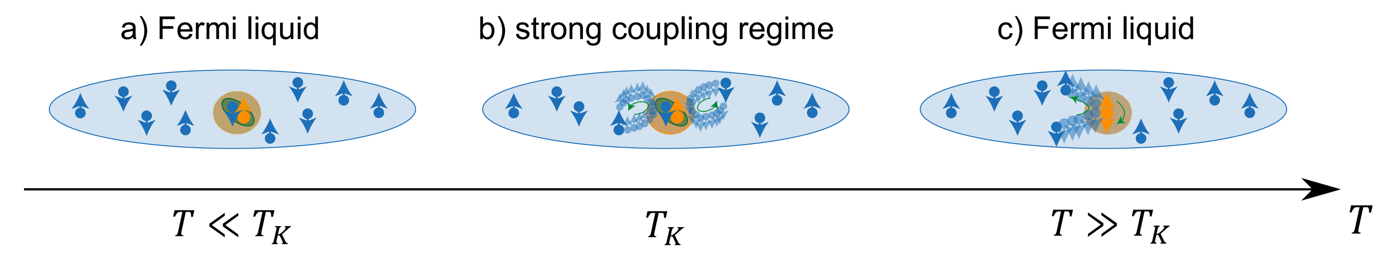


Quantum Mixtures

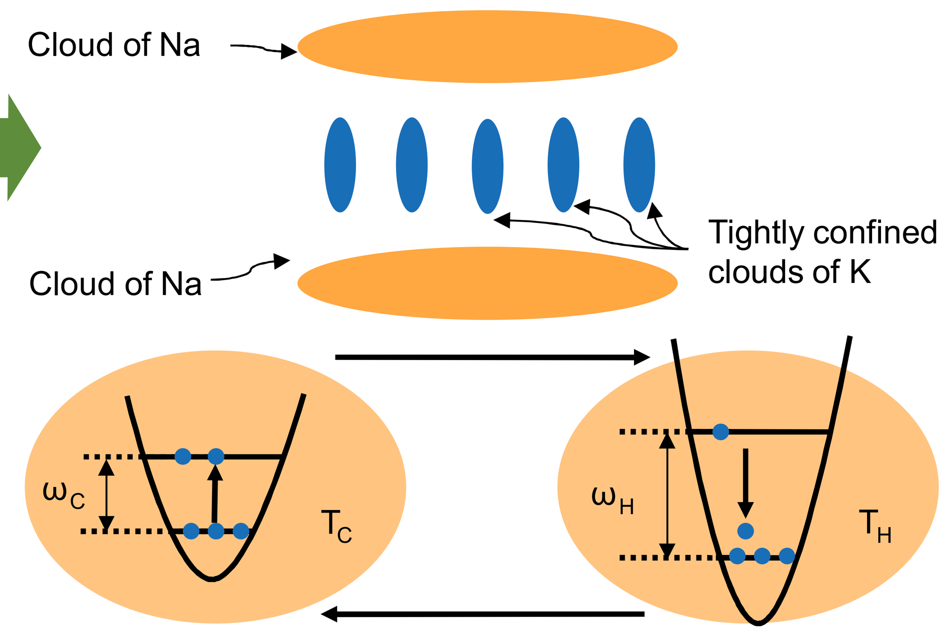
Tunable key parameter:

- atomic properties
- quantum statistics
- interspecies interaction strength and dimensionality

Kondo effect[2]



Quantum Refrigerator[1]



Goal

- Cool thermal cloud below degeneracy threshold

The Baths:

- Uncondensed Na atoms trapped in an optical dipole trap
- Large seperation to prevent atoms from tunnelling

Working Medium:

- Single K atoms in an optical tweezer array
- Thermalization with the bath through contact collisons

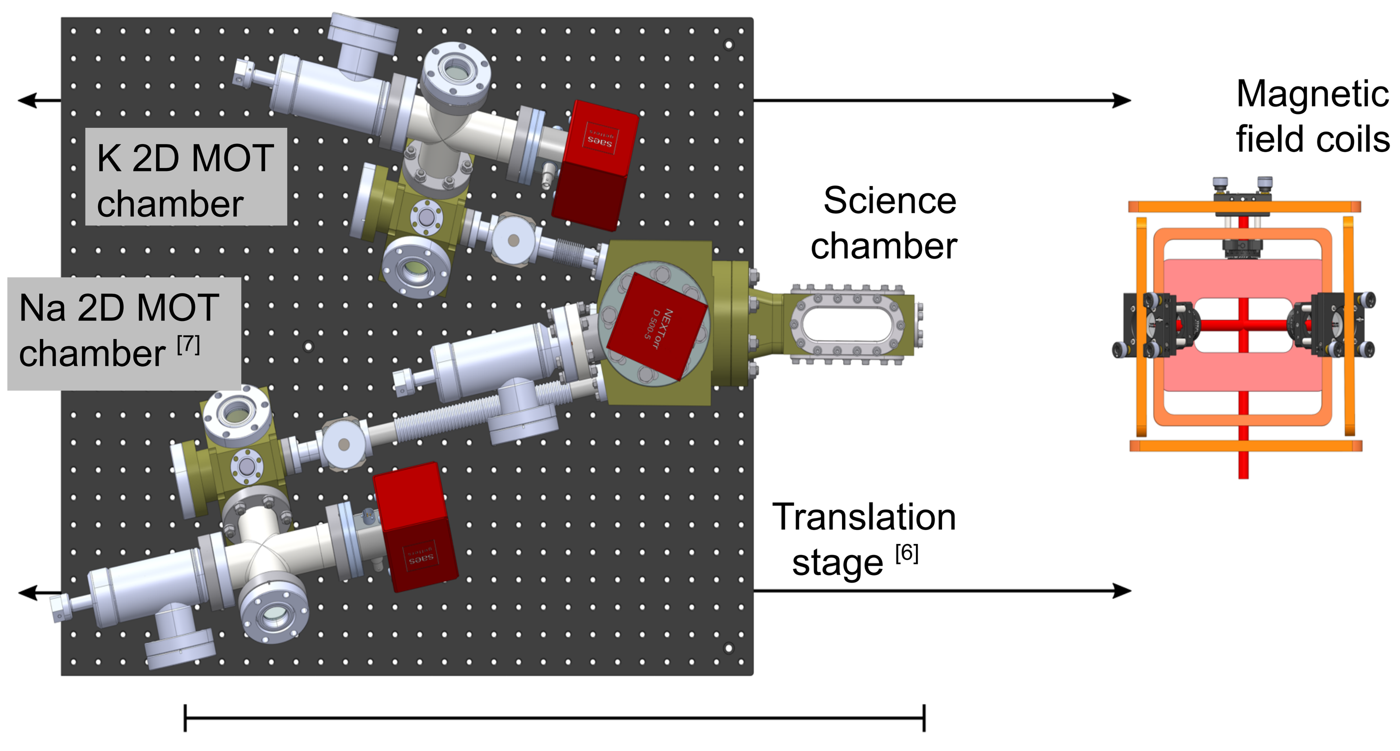
The Piston:

- Spacing between the energy levels varied by laser intensity
- Two accessible quantum states

Why Na-K?

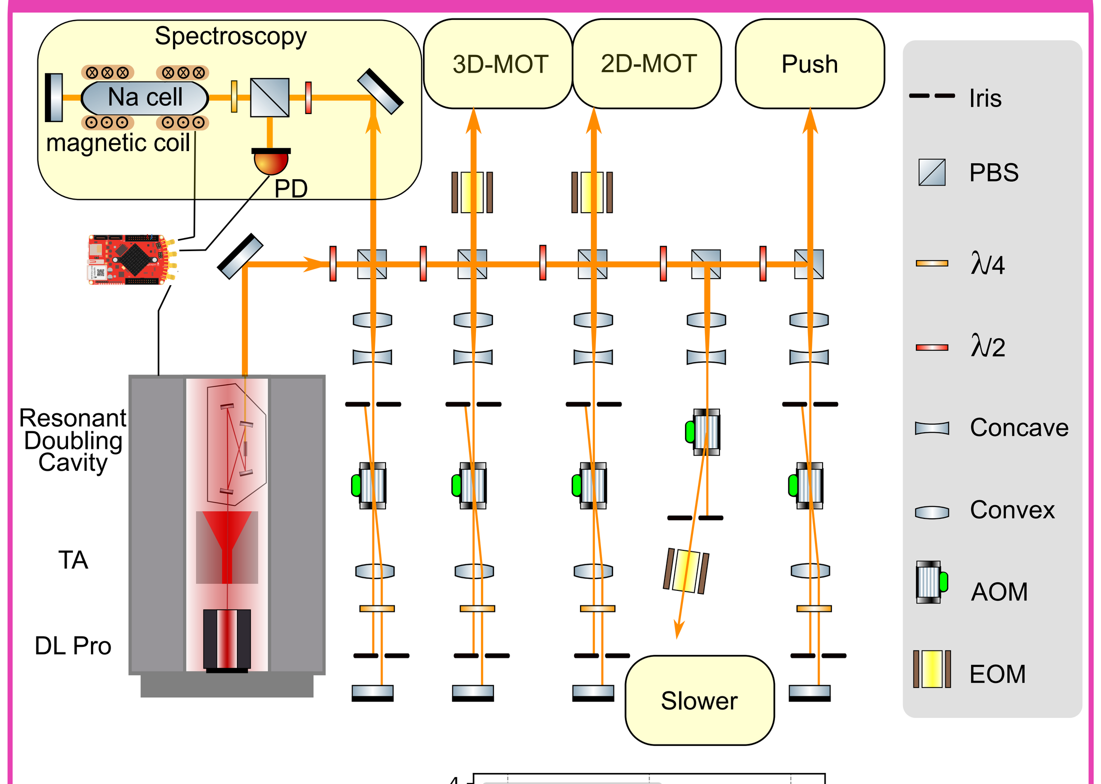
- Possibility to work with both K-39 and K-40 (Bosonic and Fermionic) in our design.
- Tuning knob of Feshbach resonances at moderate magnetic fields of less than 300 G[4,5].
- Predicted to have fast Spin Changing Collisions.

Mobile and modular vacuum system

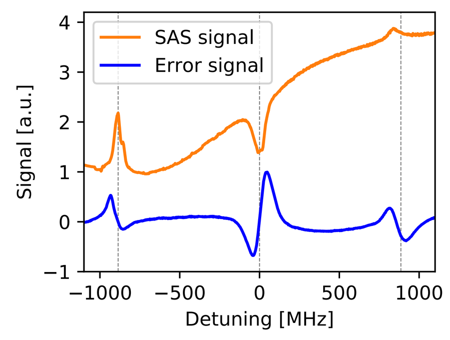


- Modularity, to work on and optimize Na and K setups separately.
- Vacuum system on a translation stage.
- Science chamber designed to give more optical access and facilitate higher numerical aperture.

Na laser system

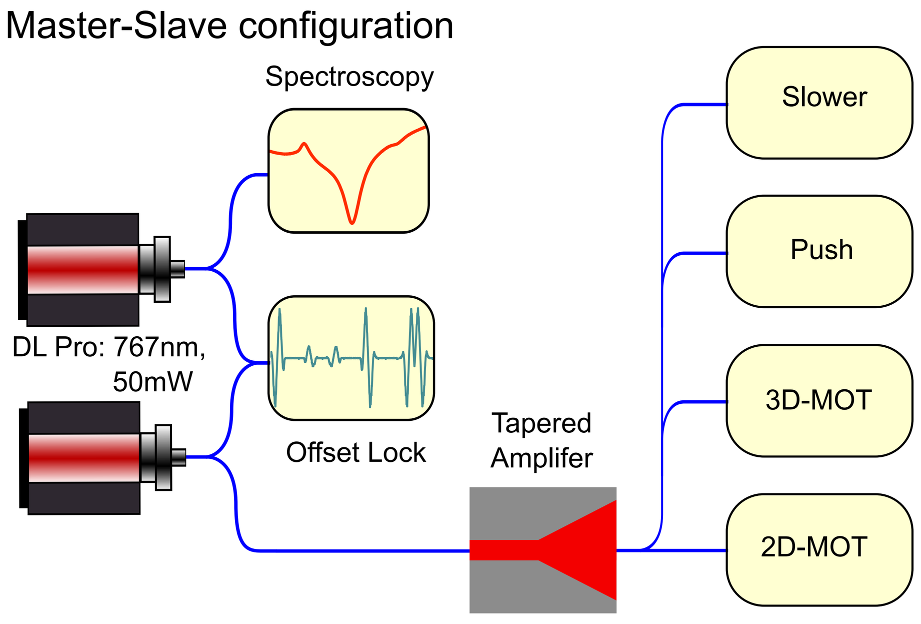


- Laser locking using Zeeman modulation

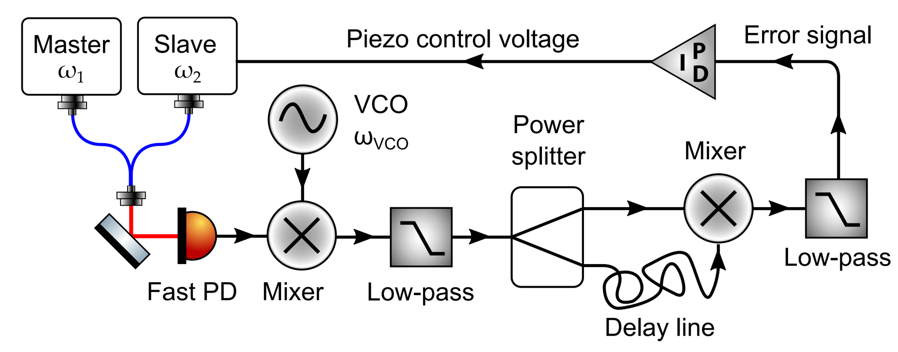


K laser system

- Master-Slave configuration



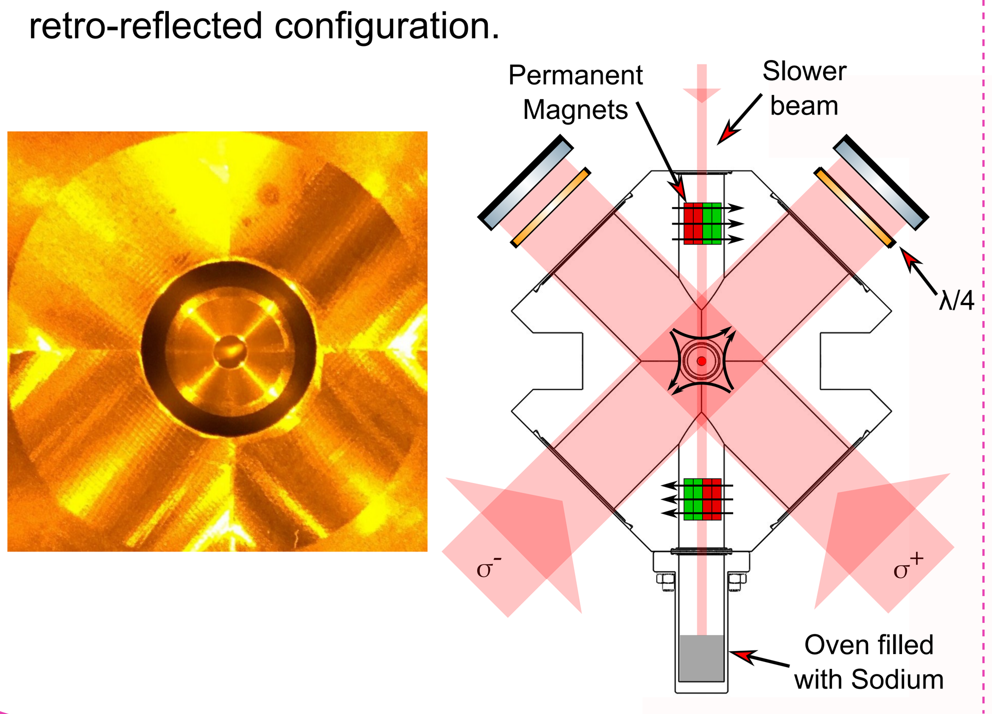
- Offset Lock



Towards a quantum heat engine

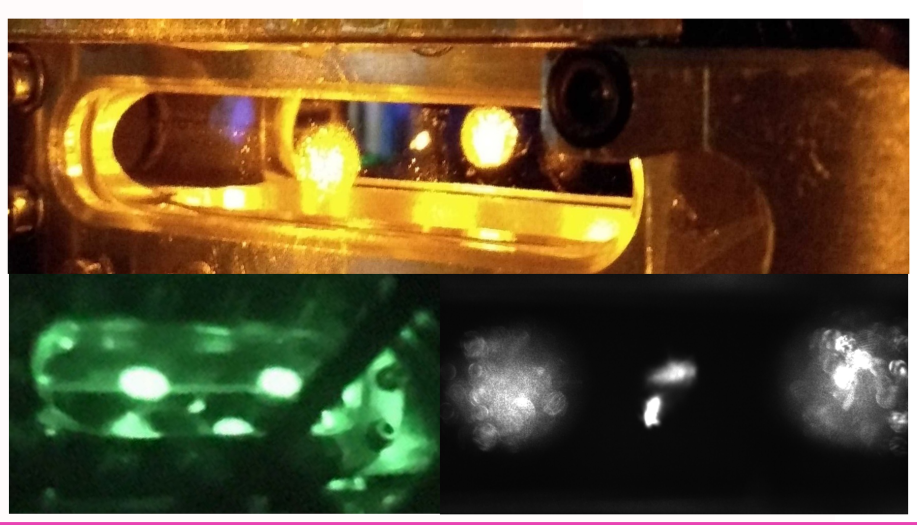
1 Seperated 2D magneto-optical traps

- Quadrupole magnetic field produced by four stacks of permanent magnets.
- Two red-detuned circularly polarized laser beams in retro-reflected configuration.



2 Dual species 3D magneto-optical trap

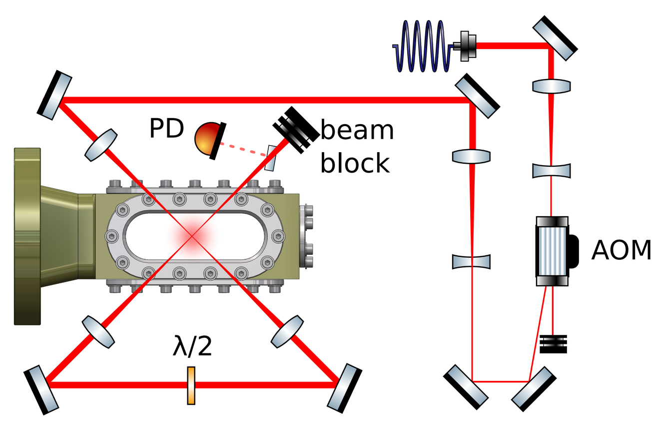
- Near-resonant push beam transports pre-cooled atoms into science chamber.
- Three laser beams in retro-reflected configuration and magnetic quadrupole field.
- Characterize cold atoms using absorption imaging.
- Loading time: 3s



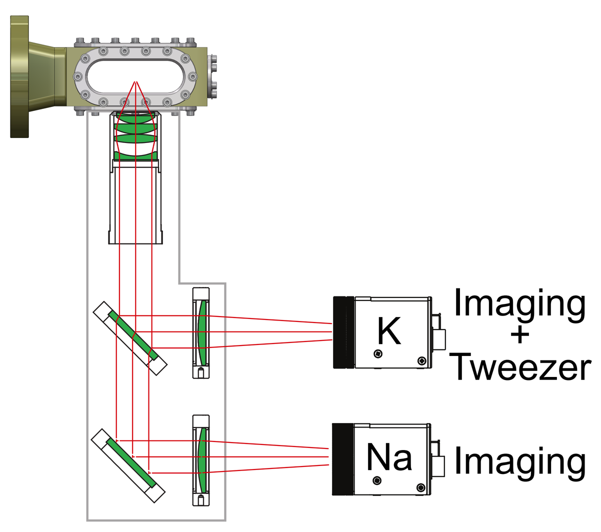
3 Na Crossed Optical Dipole Trap

- Trapping potential: $V(r) \propto \frac{I(r)}{\Delta}$
- IPG Fiber Laser: 100W at 1070nm.
- Focused beam waist of 50μm

→ Trap depth: ~2mK.



3 K Optical Tweezers



- TiSa Laser: 2W at 780nm.
- Focusing through Imaging Objective
- Mobile tweezer arrrays generated by an AOD[8]

Outlook

- With the achievement of Na and K 3D MOT, we are actively working towards achieving the Na BEC in optical dipole trap and K tweezers.
- We are also implementing an optimized high resolution imaging scheme for the experiment.
- An innovative thermometric technique[9] will be used for non-demolition measurements.
- Techniques for active magnetic field stabilisation (based on NV centres in diamond) are also being developed for tight control over Feshbach fields.
- The experiment control system should facilitate remote access to potentially run the machine 24 X 7.

References

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Emmy Noether-Programm DFG