**Negative Absolute Temperature for Motional Degrees of Freedom**

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**Experimental Realization**

**Vacuum chamber**

- MOT chamber and coils
- 85-84 dispersive & magnetic transport
- Blue-detuned light to prevent Maricamp losses in center
- Temporal amplifier with 100 at 768 ns
- Cloud centered on symmetry axis, coils also usable for feedback field

**Optically plugged quadrupole trap**

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**Crossed optical dipole trap and blue-detuned lattice**

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**BEC with Tunable Interactions**

- Two-state in absolute ground state
- 3D-87F3 Feshbach resonance
- 87Rb Feshbach resonance

**Feshbach Induced Mott Insulator**

- Mott Insulating
- Phase diagram for repulsive BEHM at $T = T_c$ (overestimate)
- Phase diagram for attractive BEHM at $T = T_c$ with shifted $g$

**Creation of Negative Temperature States in Optical Lattices**

**What is negative absolute temperature?**

- $P_i = \sum_{\ell} a_{\ell}^{\dagger} a_{\ell}$
- $\sum_{\ell} a_{\ell}^{\dagger} a_{\ell} = c a_0^2$

**Energy bounds of the Bose-Hubbard Hamiltonian**

- $H = -J \sum_{\ell} \left[ a_{\ell}^{\dagger} a_{\ell+1} + a_{\ell+1}^{\dagger} a_{\ell} + \frac{1}{2} \right] + U \sum_{\ell} n_{\ell}$

**Scheme for creation of negative temperature states**

- Quench of interaction $U$ and external confinement $V$ of a bosonic Mott insulator

**Phase diagram and negative pressure**

- Density matrix: $\rho = \sum_{\ell} a_{\ell}^{\dagger} a_{\ell}$
- Energy differentials: $E_k - E_0 = \sum_{\ell} \left[ a_{\ell}^{\dagger} a_{\ell} - \frac{1}{2} \right] + U \sum_{\ell} n_{\ell}$
- General stability conditions: $|F| / |P| \geq 8$

**Stability**

- Coherence lifetime vs. horizontal trap frequency
- Coherence lifetime vs. interaction

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**The Apparatus**

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