We aim to cool (remove mechanical energy from) the motion of a harmonic oscillator, like a mass on a spring, to its quantum mechanical ground state.

Motivation – Testing Quantum Mechanics and Gravity
Once the energy is near the ground state energy, we can:
- Perform Fundamental Tests of QM
- Generate Interesting States

Finally, we aim to help answer the question
- Is gravity quantum mechanical?

How Will we Do This?
To test the quantum mechanical effects of gravity, we intend to create a non-classical state of the harmonic oscillator. For instance:
- A spatial superposition state
- A squeezed state of the harmonic oscillator
- Changes to the evolution of quantum uncertainty

References
1 R Penrose Mathematical Physics 2000
3 H Yang et al. PRL, 110 (2013)

Feedback Cooling the Motion of a Magneto-Gravitationally Trapped Microsphere
Bradley R Slezak, Charles W Lewandowski, Brian D’Urso
Montana State University

Introduction – Cooling a Mechanical Oscillator
We create a harmonic oscillator by diamagnetically levitating a silica microsphere with a magnetic ‘trap’ consisting of permanent magnets sandwiched between ferromagnetic pole pieces:

The shape of the pole pieces generates a quadrupole field (in the x-y plane) that is gently curved upwards in the y-z plane:

Consider the potential energy of a spherical particle in this magnetic field and in the presence of gravity:

This potential creates a trap (a potential minimum and restoring force in all directions):

\[ U = \frac{1}{2} k_B T = \frac{1}{2} m \omega_0^2 (x^2) \]

\[ \omega_x/2\pi \approx 60.0 \text{ Hz} \quad \omega_y/2\pi \approx 97.0 \text{ Hz} \quad \omega_z/2\pi \approx 7.0 \text{ Hz} \]

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