BEC Interferometry and Applications

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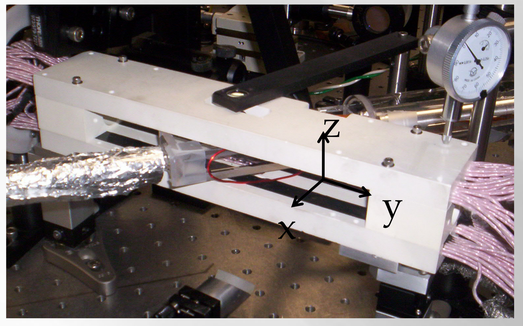
Atom Interferometry

- Manipulate atomic wave functions
- Measure phase $\psi \sim e^{-iEt/\hbar}$
- Measurement of gravity, inertial effects, atomic properties

Advantages of Condensates

- Easier to control – permit "guided wave" interferometers
- Hope for more flexible trajectories, longer interaction times
- Support atoms against gravity - shorter apparatus
- Coherent waves means high contrast

Waveguide



- Supports atoms against gravity and provide spatial confinement
- Harmonic confinement:

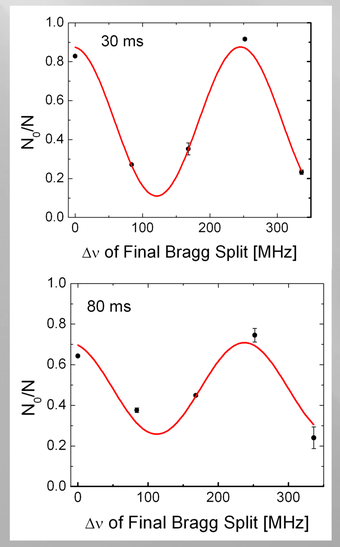
$\omega_x / 2\pi = 5.7$ Hz

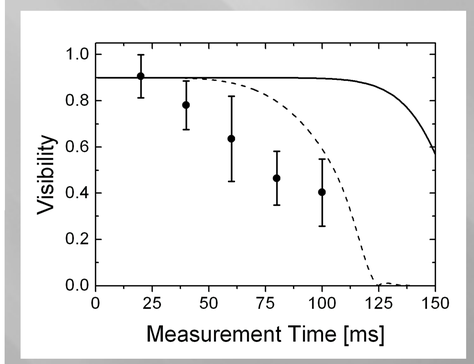
$\omega_y / 2\pi = 0.21$ Hz

$\omega_z / 2\pi = 3.3$ Hz

Weak Longitudinal Confinement Reduces Noise

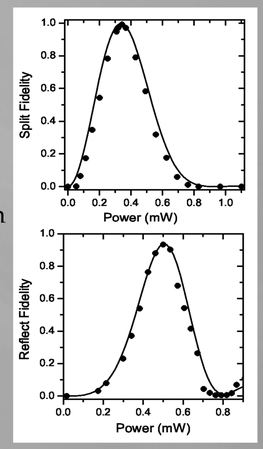
- Lower density – weaker atomic interactions
- Energy differential across wave packet $\propto \omega_y$

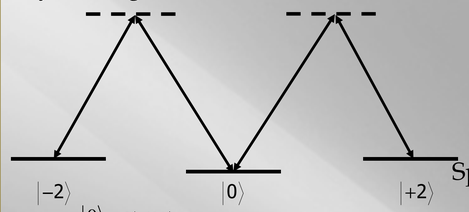




Split & Reflect Beam

- The atoms achieve spatial separation via pulses of off-resonant light
- This light forms a standing wave which acts similar to an optical diffraction gating
- Split operation is a two photon process involving an absorption and stimulated emission
- The same beam reverses the motion of the atoms by driving them from $|+2\rangle \leftrightarrow |-2\rangle$.



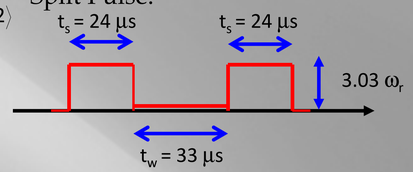


$|0\rangle$ at rest

$|+2\rangle$ moving $p = +2\hbar k$

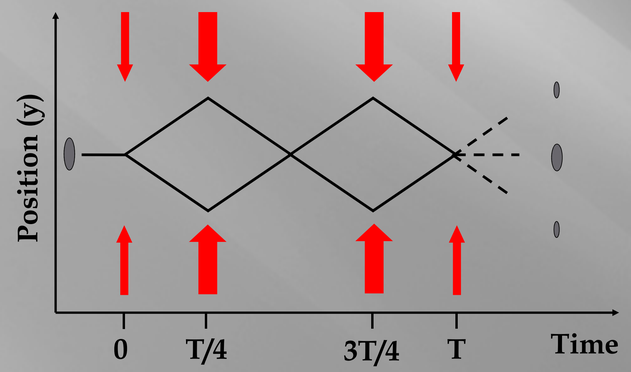
$|-2\rangle$ moving $p = -2\hbar k$

Split Pulse:



Symmetric Trajectory

- Phase $\phi = \phi(y)$, varies across packet
- Symmetric interferometer cancels the effect of these gradients



Recombination & Phase Extraction

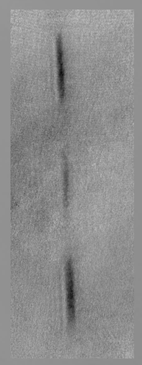
- Overlapping atoms have inference fringes too small to resolve
- The split pulse acting on $|+2\rangle, |-2\rangle, \& |0\rangle$ gives:

$$U_{Split}|0\rangle = \frac{1}{\sqrt{2}}(|+2\rangle + |-2\rangle) = |Split\rangle$$

$$U_{Split}|Split\rangle = |0\rangle$$

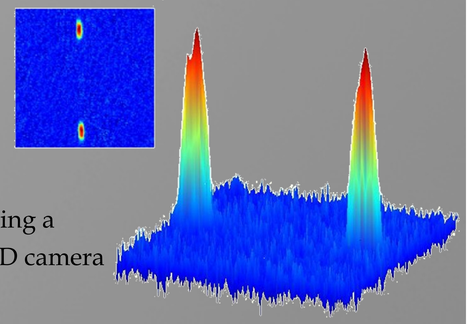
- For a phase shifted wave function, $|\phi\rangle$, we find the number of atoms coming to rest by:

$$\frac{N_0}{N} = |\langle\phi|Split\rangle|^2 = \cos^2\left(\frac{\phi}{2}\right)$$



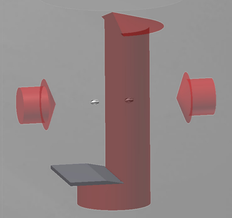
Imaging

- $\frac{N_0}{N}$ is determined by absorption imaging
- Atoms absorb resonant light, casting a shadow which we image on a CCD camera



Measurements

AC Polarizability (AC Stark Shift)

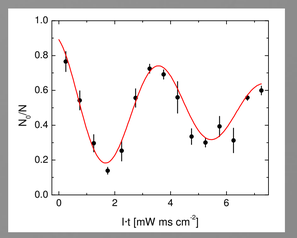


- Shine laser on one packet
- Measure induced phase

$$\Delta\phi = \frac{\alpha}{2c\hbar\varepsilon_0} It$$

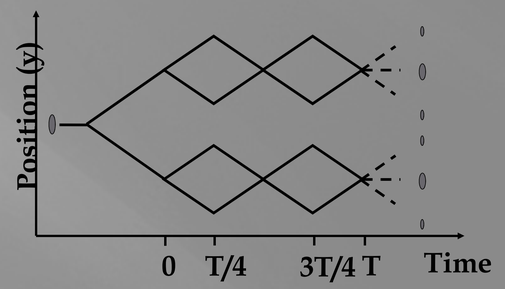
α = polarizability
I = intensity
t = pulse time

Measure α at Δ = 6.6 GHz, 13 THz
6% accuracy



Current & Future Work

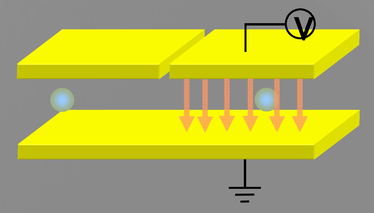
Dual Interferometer



- Noise from vibrations currently limit visibility
- Vibrations will couple to both interferometers in a dual setup

DC Polarizability

$$\Delta\phi = \frac{1}{2}\frac{\alpha_{DC}|\vec{E}|^2 t}{\hbar}$$



Sagnac

$$\Delta\phi = 4\pi A \bullet \Omega \frac{m}{\hbar}$$