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A Compact Accelerometer using High Bandwidth Atom Interferometry

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LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Comparison

Type	Noise (g/sqrt(Hz))	Drift (g/day)	Accuracy (g)
Spring/mass systems	1E-10	3E-8	N/A
Levitated superconducting spheres	< 1E-12	2E-10	N/A
Falling corner-cubes	5E-8	-	2E-9
Atom Interferometer	2E-8	-	<1E-8

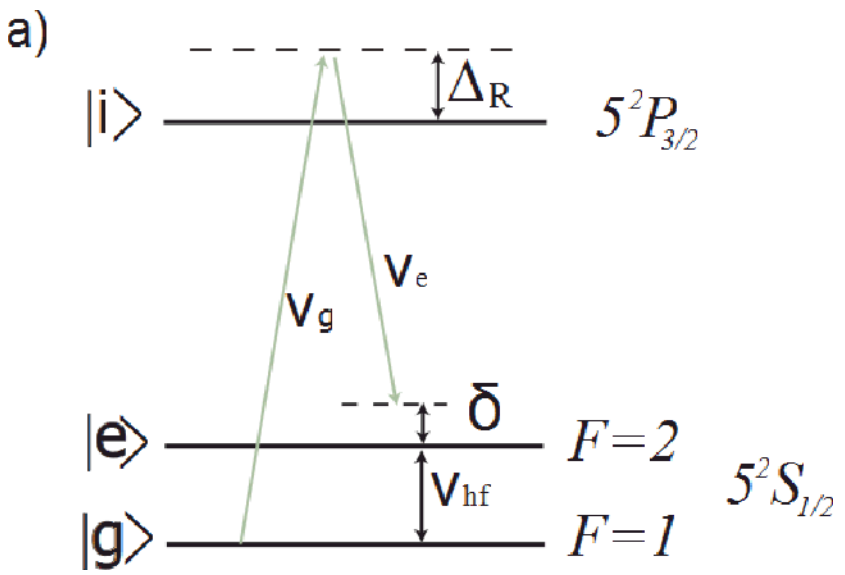
Atom Interferometers

- Typically low bandwidth, high precision
- Measured gravitational constant g to ____.
  - Long interrogation times
- Increase bandwidth (decreases sensitivity). Wider range of applications
  - Inertial navigation
  - Seismic sensing

Doppler Sensitive Raman Transitions

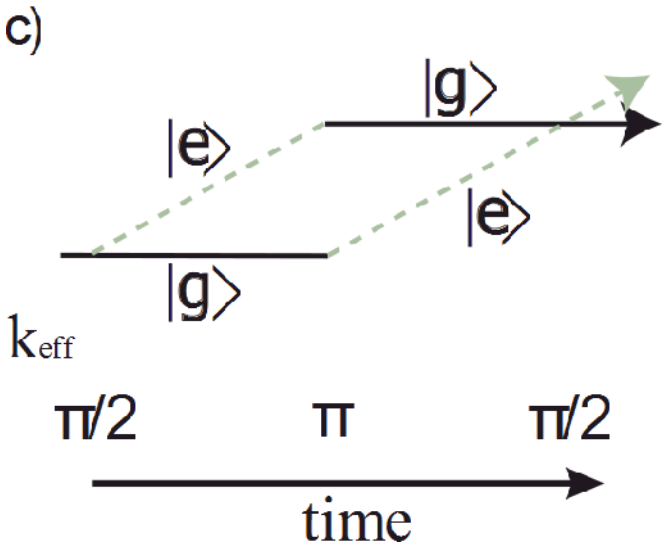
- Hyperfine ground states of Rb87 coupled via a two photon Raman transition.
- Large detuning Δ used to suppress spontaneous emission.
- State oscillates between hyperfine ground states at generalized Rabi frequency:

$$\Omega = \left(\frac{|\Omega_1|^2}{\Delta} - \frac{|\Omega_2|^2}{\Delta} - \delta \right)^2 + 4 \frac{|\Omega_1|^2 |\Omega_2|^2}{\Delta}$$



Atom Interferometer

- Atoms which undergo the transition gain a momentum kick of keff.
- By using a π/2 pulse, the atoms are placed in a superposition of excited and ground state
- The π/2 – π – π/2 sequence creates an interferometer, as shown to the right.



Accelerometer

- The phase shift along each path is given by

$$\phi_i = k_{eff} \cdot x_i$$

- Adding up the total phase over the interrogation time:

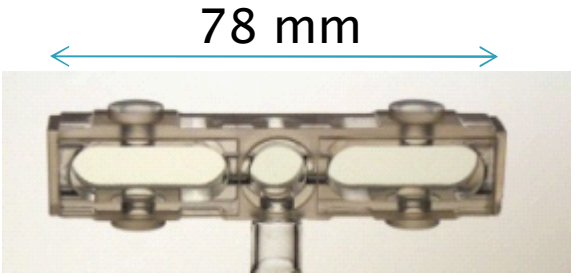
$$\frac{\Delta\phi}{T^2} = \frac{1}{k_{eff}} \frac{\left(x_1 - 2x_2 + x_3\right)}{T^2}$$

- The factor on the right is the finite difference formula for the average acceleration. Thus:

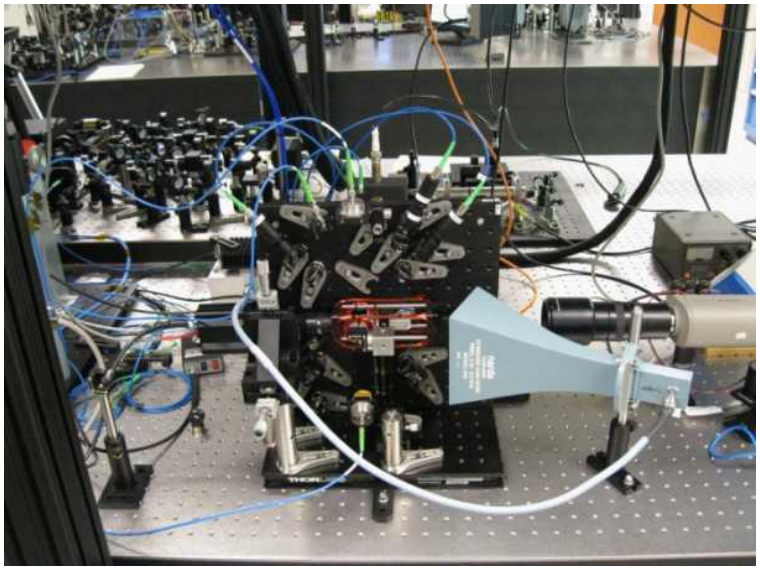
$$a = \frac{\Delta\phi}{k_{eff} T^2}$$

Experiment

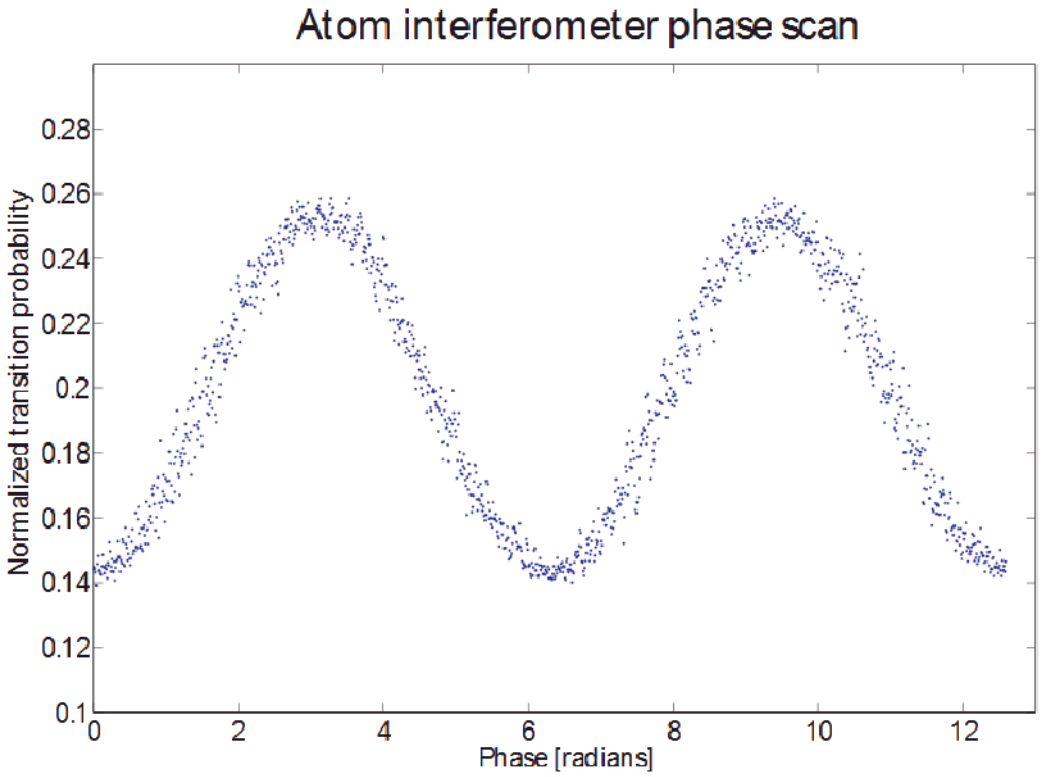
- ~1E6 Rb87 atoms loaded into a MOT from vapor.
- Timing sequence:
  - Drop
  - Subdoppler cool (~2 ms)
  - State Preparation (~1 ms)
  - Pulses (~10 ms)
  - Detection (~1 ms)
  - Recapture (~15 ms)



Compact cell, built by Precision Glassblowing

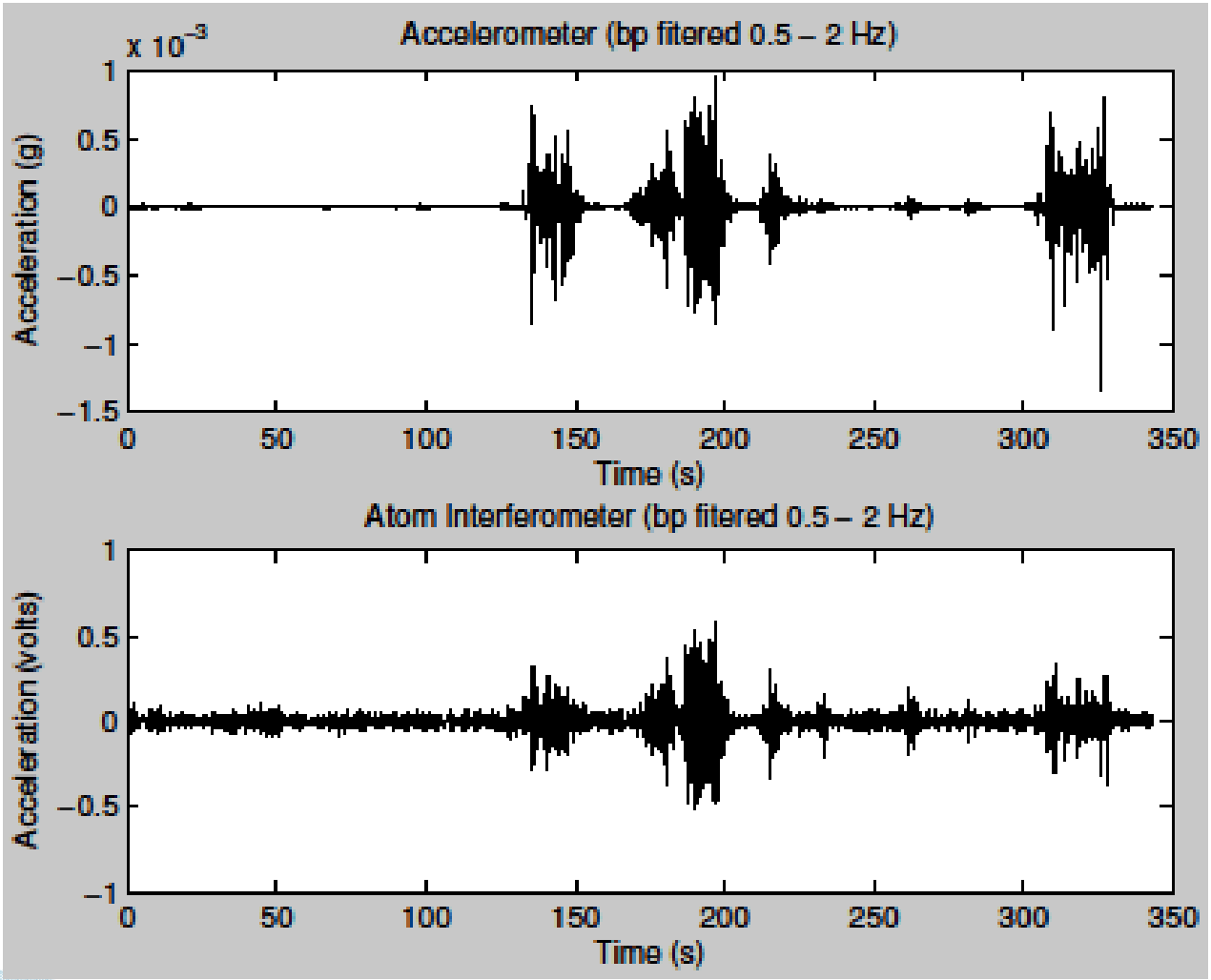


Preliminary Results

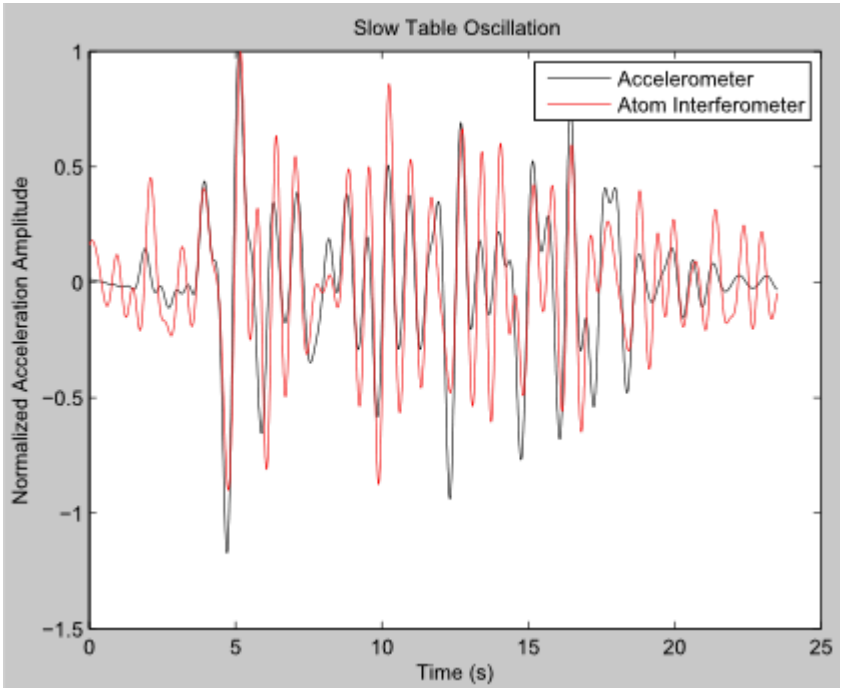


- Ramsey fringes using the π/2 – π – π/2 pulse sequence.
  - T = 5 ms, 29 Hz data rate.
- π phase shift corresponds to 795 μg.

Comparison to Accelerometer



Comparison to Accelerometer

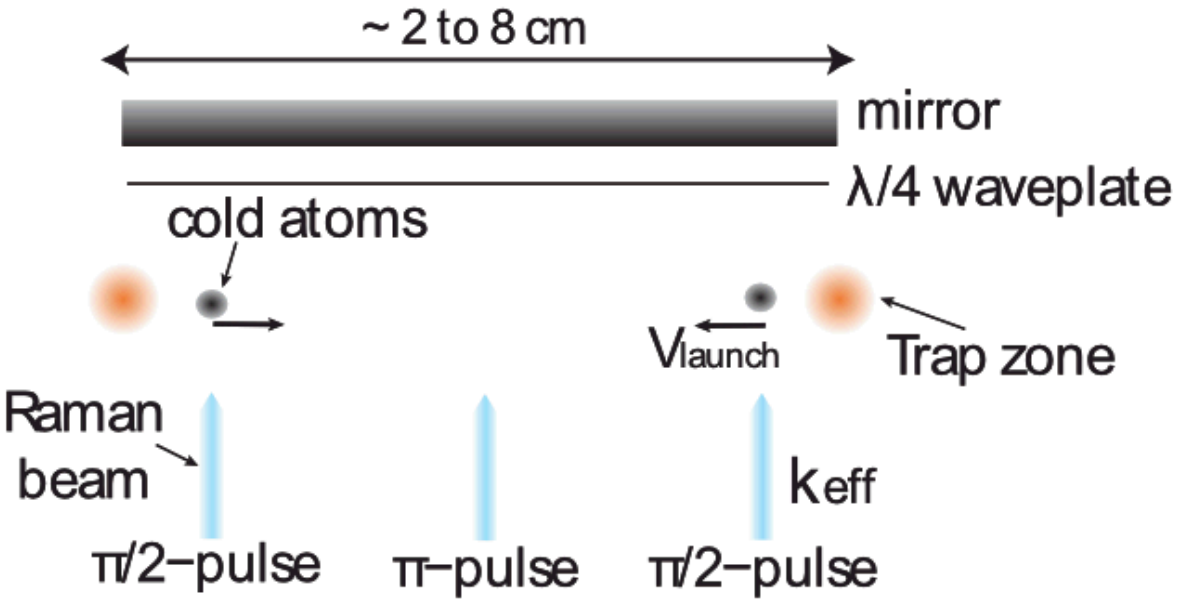


Limitations

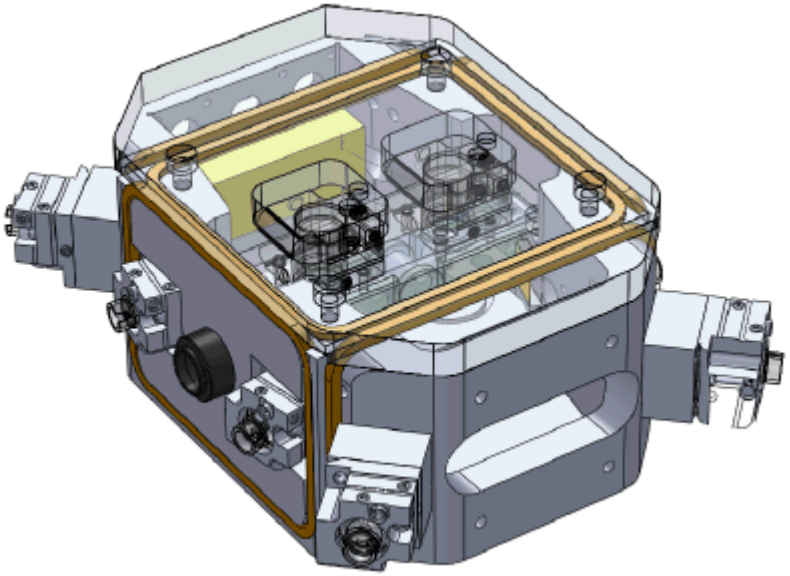
- Raman beams propagate on different fibers. Phase noise from beams is transferred to the atoms.
- Temperature of atoms (~100 μK) results in dephasing effects.
  - Want to be ~1 μK

Future Plans

- Simultaneously measure rotation and acceleration with a double MOT configuration.



Future Plans



CAD concept of enclosure for vacuum cell, with magnetic shielding and fiber ports.