Using Atom Interferometer for Inertial Sensing

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Grand Vision

- Accelerometry
- Gyrometry
- Gravitation Theories
- Precision Measurements of Time: atomic clock
- Precision Measurements of E and B: magnetic and electric dipole moments

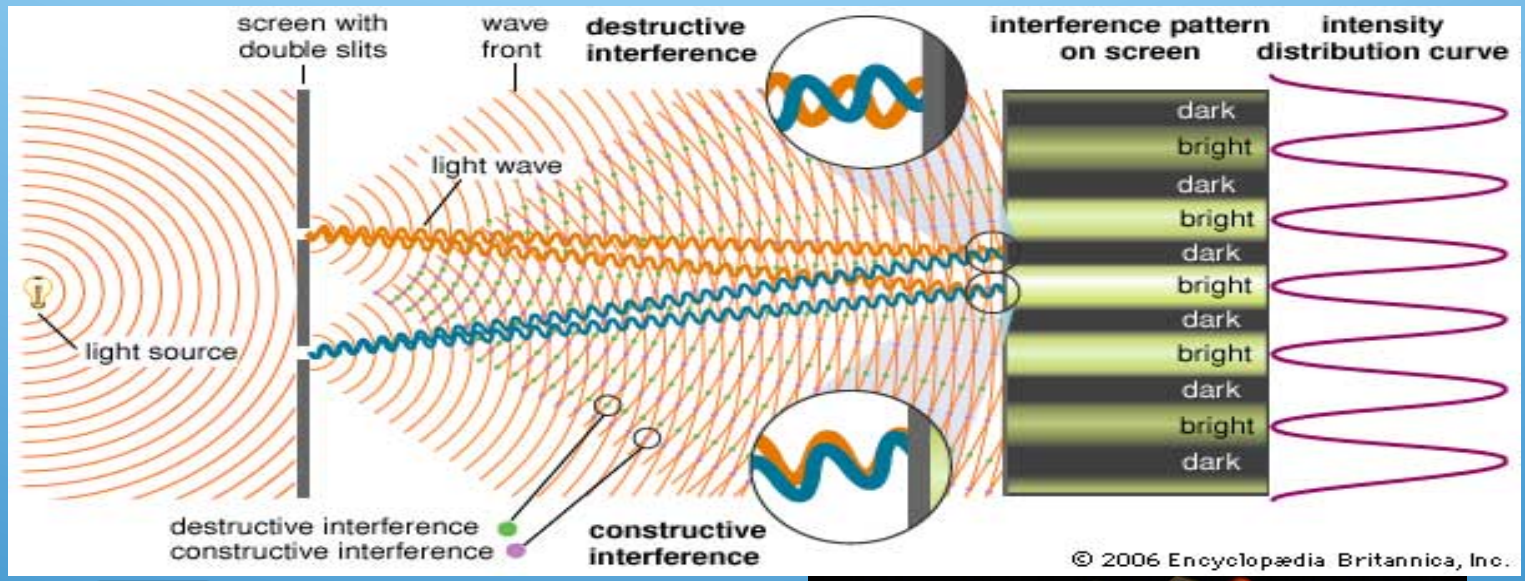
Recent History of Interferometer

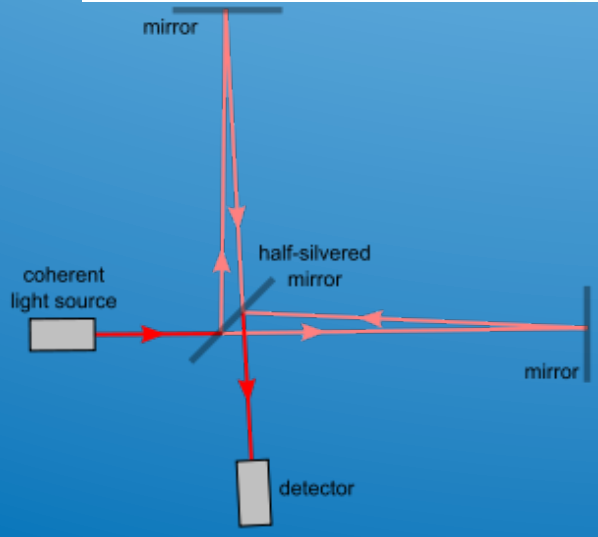
- Late 1970s neutron interferometers measured acceleration and rotation of Earth
- In 1991, atom interference techniques were used in proof-of-principle work to measure rotations and accelerations

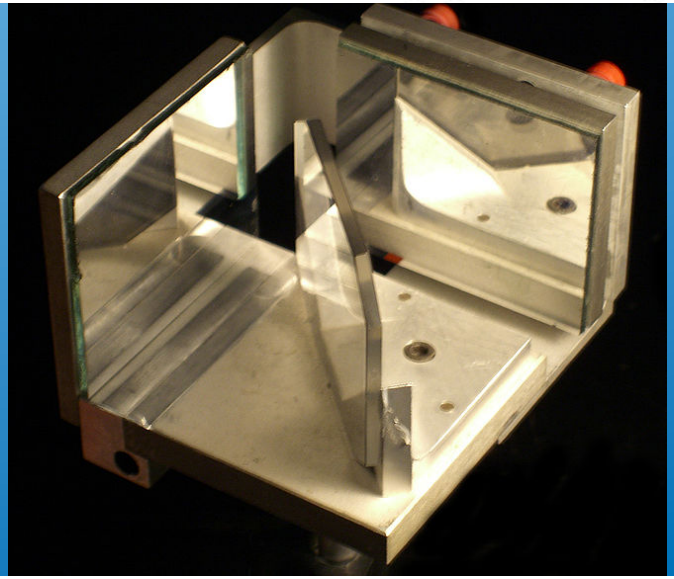
What is an Interferometer?

- Exploits the quantum nature of matter-waves by using coherent source
- Measurements are dependent on geometry of instrument
- Superposition combines separate waves together in a way that will cause the result of their combination to have some meaningful property that is diagnostic of the original state of the waves
- Waves with similar frequency and phase produces constructive interference and out of phase waves produces destructive interference
- Generally uses light in the 400 – 700 nm range

Basic Interferometers

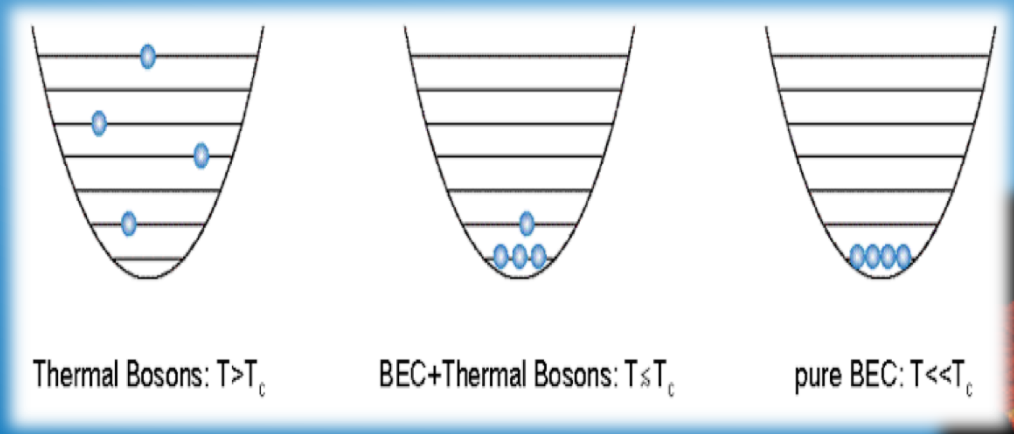


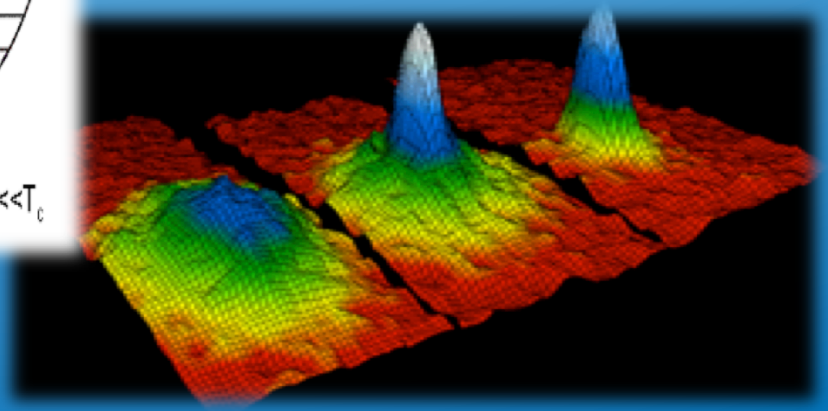




Atoms and BEC Condensate

- Dilute, dense gas of weakly interacting bosons
- Ultra-Cold conditions ranging from 10-1000 nK
- Quantum wave functions overlap one another
- Confined by external potential and cooled
- Leads to occupation of lowest quantum state of system



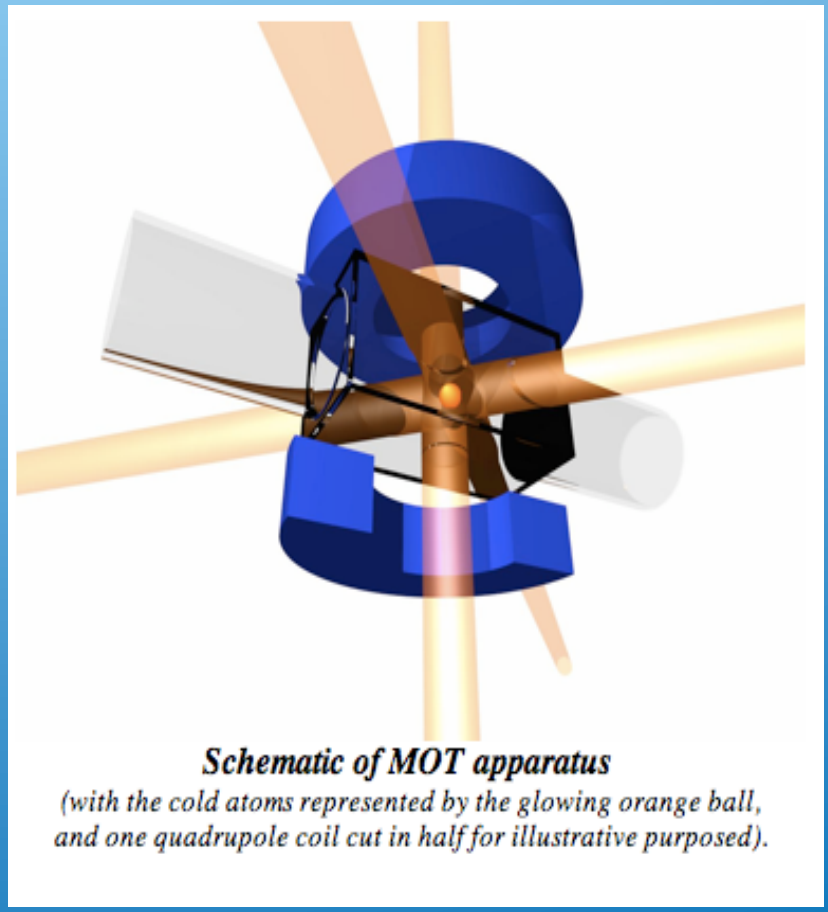


Atom Interferometer

- Short de Broglie wavelength of atoms makes precise interferometer
- Accurate measurements are dependent on the atomic density
- Measures the phase-shift acquired by atoms through different coherence preserving paths
- Complex instrument exploiting BEC
- Must have physically separated paths to be used as Inertial Sensor.
- Can be made relatively compact

Basic Inertial Sensor

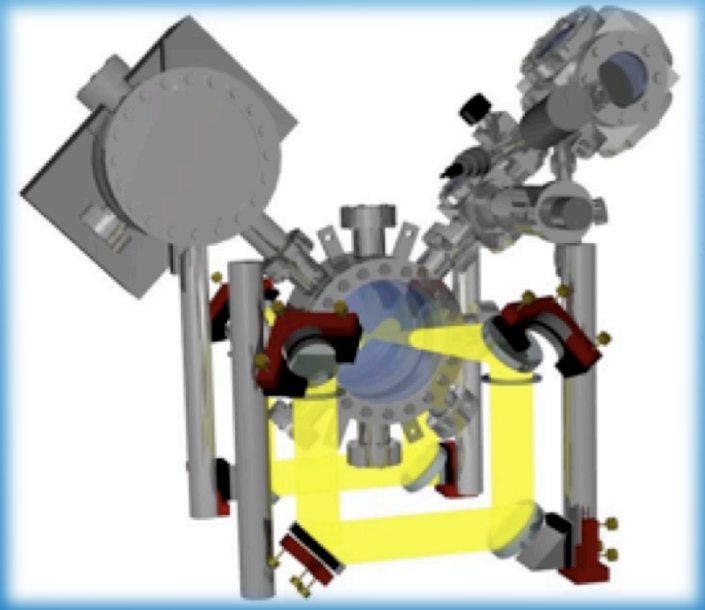
- Vacuum chamber
- Laser sources for cooling and coherent manipulation
- Magneto-optical trap
- Atom-interferometer must have physically separated coherent propagation paths to detect inertial forces



Schematic of MOT apparatus
(with the cold atoms represented by the glowing orange ball, and one quadrupole coil cut in half for illustrative purposed).

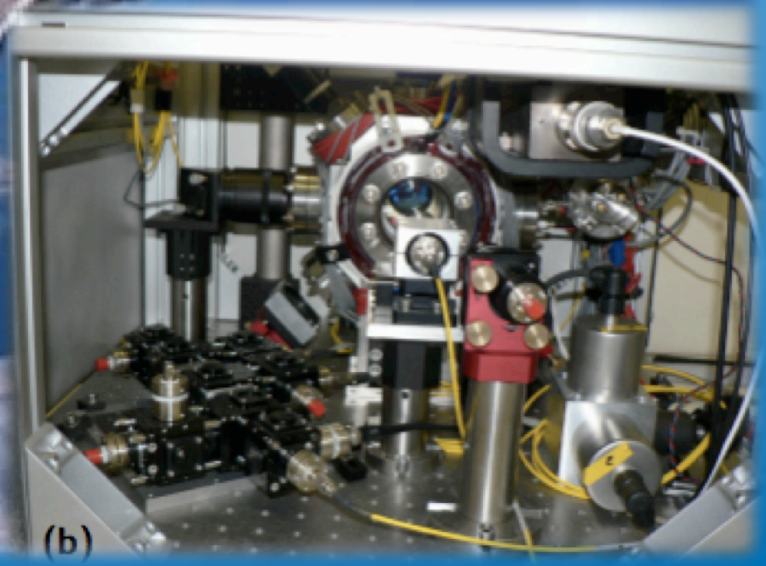
Inertial Sensor: Boson-Fermion Atom Interferometer

- Part of the ICE collaboration (Interf´erometrie Coh´erente pour l'Espace)



I.C.E. Inertial Sensor at Laboratorie Charles Fabry, Institut d'Optique

- Placed in airplane during ballistic flights to measure microgravity
- Observed the interferometric suspension of a free-falling Bose-Einstein condensate
- Rotation of interferometer leads to Sagnac shifts, but can be eliminated
- Clouds of ^{87}Rb and ^{40}K in MOT are released during free fall



I.C.E. Preliminary Results

- Preliminary results show that laboratory experiments can be adapted for this new experimental platform
- Pave path for high-precision inertial sensors
- Requires further progress on achieving longer interrogation times during

Future Outlook

- Geodesy
- Geology
- Deep space inertial navigation
- Experiments in general relativity
- Experiments in gravitational physics
- Contribute to a deeper understanding of the beginning, development, and the fate of the universe. May even discover new forces beyond those currently known

Summary

- Atom interferometer can be used as inertial sensor
- Inertial sensor uses BEC and the short wavelength of atoms relative to geometry of apparatus makes for a precise device
- Inertial sensor used in ICE to test equivalence principle
- Has many useful applications in other areas of research