Lecture 6: The Art and Craft of an Atomic Clock

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Brief Discussion

- Clock Transition
- Allan deviation as a measure of clock stability.
- Ramsey sequences and their modifications for precision.

Introduction to Atomic and Optical Clocks

- Principles of the operation of an atomic clock.
- Overview of atomic clocks: Cs clock, ion clock, neutral atom clock, and nuclear clock.
- Applications:
  - GPS, fundamental physics (gravitational redshift, time dilation).
  - International time standards and earth observation.

Systematic Effects in Optical Clocks

- Overview of systematic vs. statistical uncertainties.
- Detailed examples of systematic effects:

1. Trap-induced effects and magic wavelength operation.
2. Blackbody radiation (BBR) shifts and mitigation through temperature modeling.
3. Doppler broadening and optical lattice trapping.
4. Zeeman shifts and field-insensitive transitions.
5. DC Stark shifts and stray electric field shielding.
6. Light (AC Stark) shifts and laser intensity control.
7. Line pulling effects from nearby transitions.
8. Density shifts due to atom-atom interactions.
9. Atom-optical modulation (AOM) chirp minimization.
10. Frequency comb phase noise.
11. Tunneling shifts in optical lattices.
12. Differential g-factor effects and transition selection.
13. Background gas collisions and ultra-high vacuum conditions.
14. Thermal expansion of clock components and stabilization.
15. Probe-induced shifts, Gouy phase of a Gaussian beam.