N-resonance characterization for compact atomic clocks

Cindy Hancox[1], Irina Novikova[2], Yanhong Xiao[1], David Phillips[1], Ronald Walsworth[1,3]

[1]*Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, 02138*

[2]*Physics Department, College of William and Mary, Williamsburg, VA, 23187*

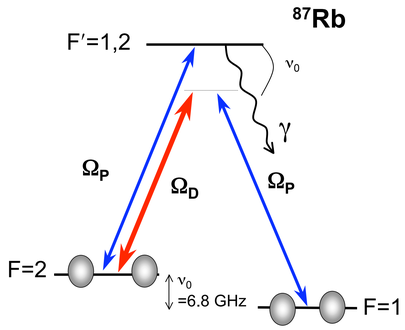
[3]*Physics Department, Harvard University, Cambridge, MA, 02138*

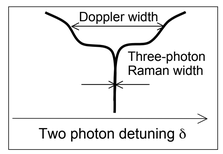
Introduction

N-resonance is an all-optical three-photon-absorption resonance which could provide an improvement over Coherent Population Trapping (CPT) for atomic clocks

- Improved light shift compensation
- Robust resonance contrast at higher-buffer gas pressures

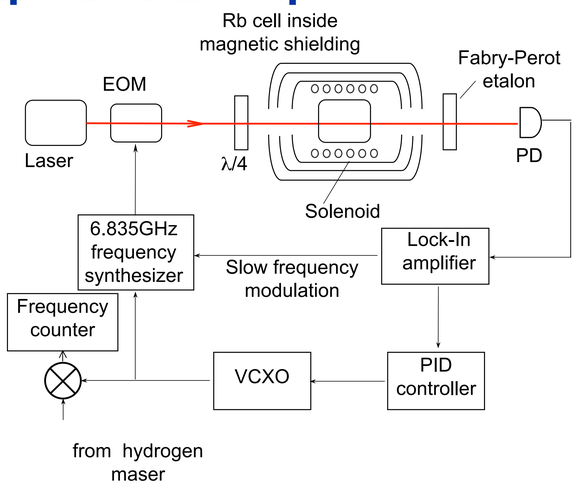
Three-photon absorption resonances





When the probe field (Ω_p) and drive field (Ω_D) have a difference frequency equal to the hyperfine frequency (ν_0) an absorption resonance is observed.

Experimental setup



Publications

A.S. Zibrov *et al.*, Phys. Rev. A **65**, 043817 (2002)

S. Zibrov *et al.*, Phys. Rev. A **72**, 011801(R) (2005)

I. Novikova *et al.*, Opt. Lett. **31**, 622 (2006)

I. Novikova *et al.,* Opt. Lett. **31**, 2353 (2006)

Light-shift compensation

analytical modeling:

When $\Delta \approx \frac{\gamma}{2}$

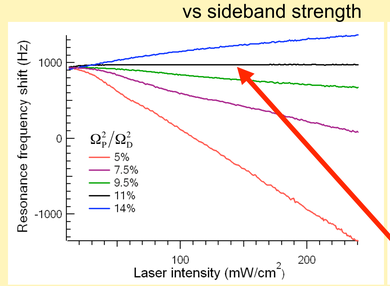
$$\delta \approx -\frac{\Omega_D^2}{2\nu_0} + \frac{\Omega_P^2}{\gamma} - \frac{2\Omega_P^2}{\gamma^3}\left(\Delta - \frac{\gamma}{2}\right)^2 + \ldots$$

For laser detuning, $\Delta = \frac{\gamma}{2}$, and field intensity ratio,

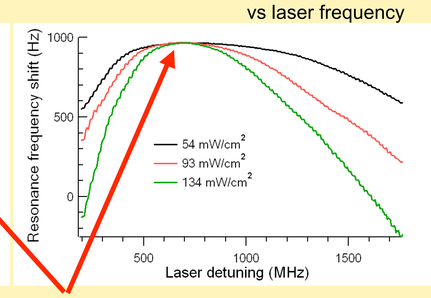
$\frac{\Omega_P^2}{\Omega_D^2} \approx \frac{\gamma}{2\Delta}$, light shift vanishes!

measurements:

vs sideband strength



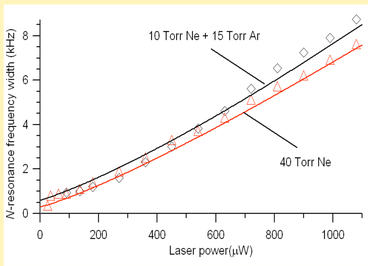
vs laser frequency



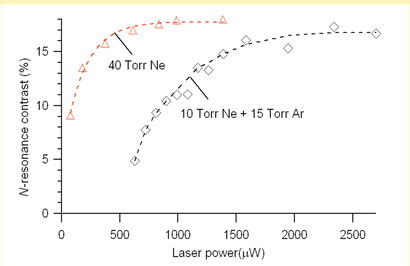
light-shift vanishes!

Robust performance at higher buffer-gas pressures

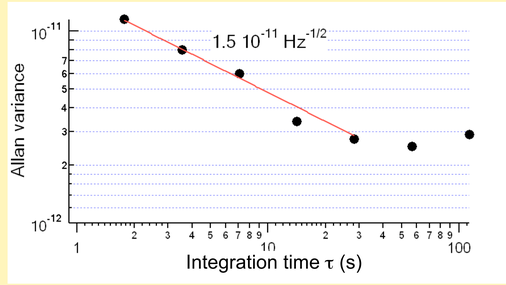
linewidth



contrast



Clock stability



Long-cell studies



Length: 7.5 cm
Buffer gas: 35 Torr Ne+Ar+N_2
Temperature: 55°C

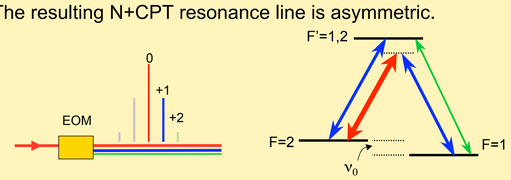
Thin-cell studies

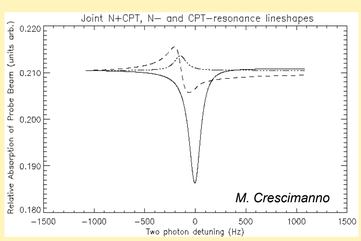


Length: 1 mm
Buffer gas: 100 Torr Ne+Ar+N_2
Temperature: 115°C

N+CPT

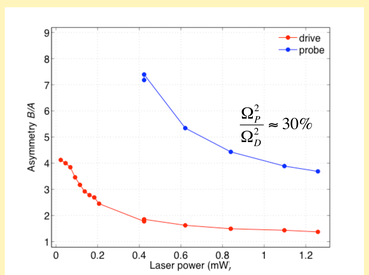
- Light shifts for the N-resonance vanish when $\frac{\Omega_P^2}{\Omega_D^2} \approx \frac{\gamma}{2\Delta}$.
- For the high buffer-gas pressures required to maintain atomic ground-state coherence in compact cells, a large fractional probe intensity is required.
- The phase modulation applied to the laser field to produce the large probe intensity creates an additional sideband which forms a CPT system with the probe.
- The resulting N+CPT resonance line is asymmetric.





Modulation transfer

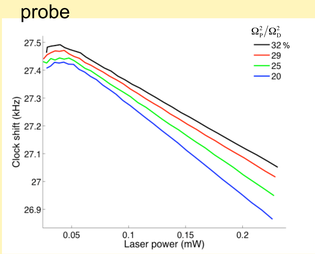
- The drive field resonance is more symmetric since it does not participate in the CPT system.
- While the drive field is not directly phase modulated at the lock-in frequency, a lock-in resonance arises due to modulation transfer via the Rb atoms.



Light-shift compensation

- The addition of the CPT system to the probe resonance makes light-shift compensation problematic.
- Light-shift compensation on the drive field resonance is more ideal.

probe



drive

