N-resonances and atomic clocks

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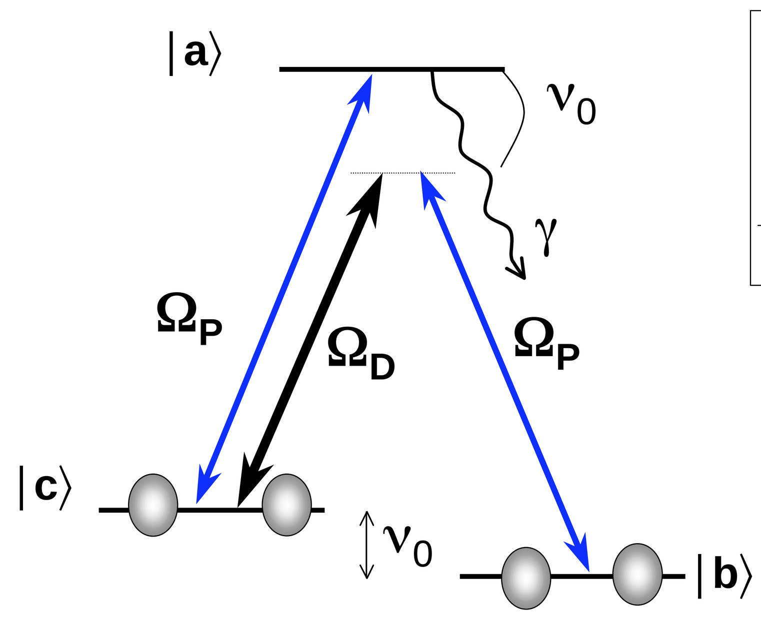
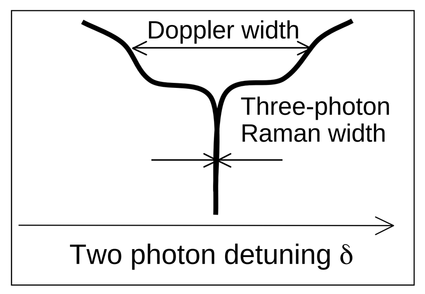
Introduction

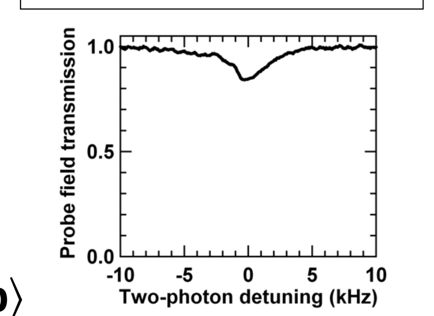
N-resonance is an all-optical three-photon-absorption resonance which may provide an alternative to Coherent Population Trapping (CPT) for atomic clocks:

- Improved contrast compared to CPT: 15% vs. 2-4%.
- Cancellation of first-order light-shifts and power dependence.

Three-photon absorption resonances

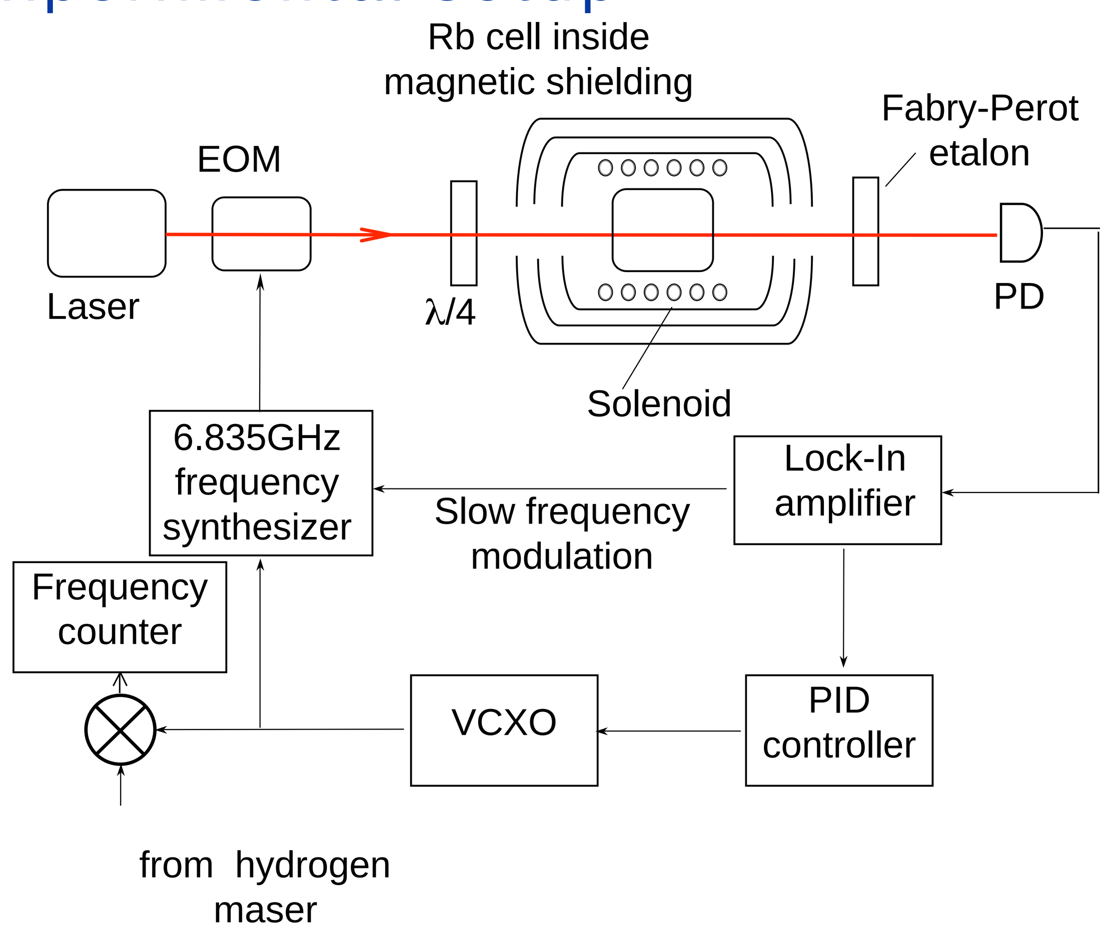




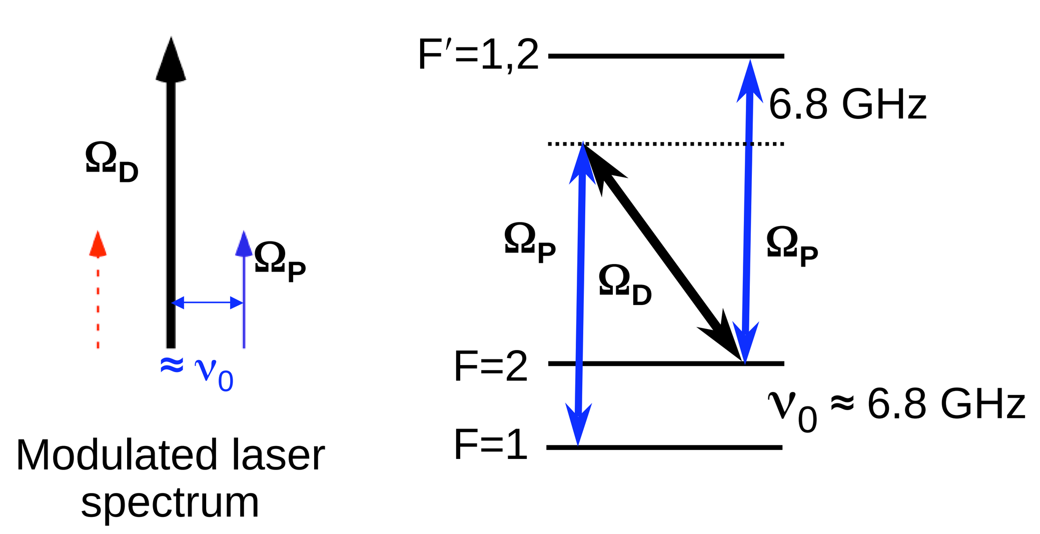


When the probe field (Ω_p) and drive field (Ω_D) have a difference frequency equal to the hyperfine frequency (ν_0) an absorption resonance is observed.

Experimental setup

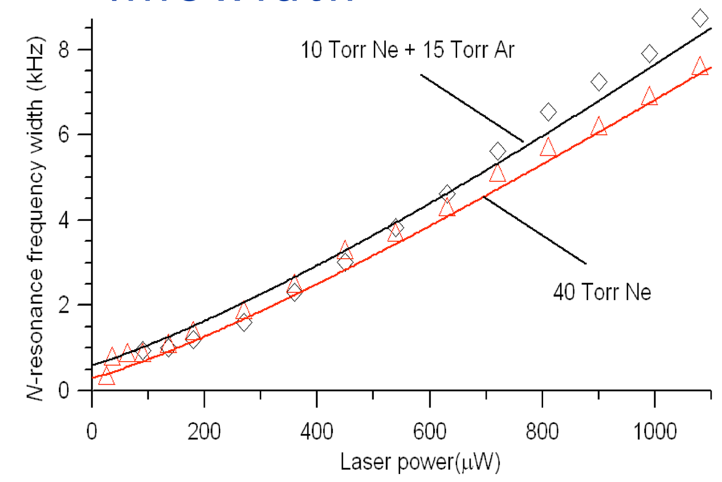


^{87}Rb level diagram

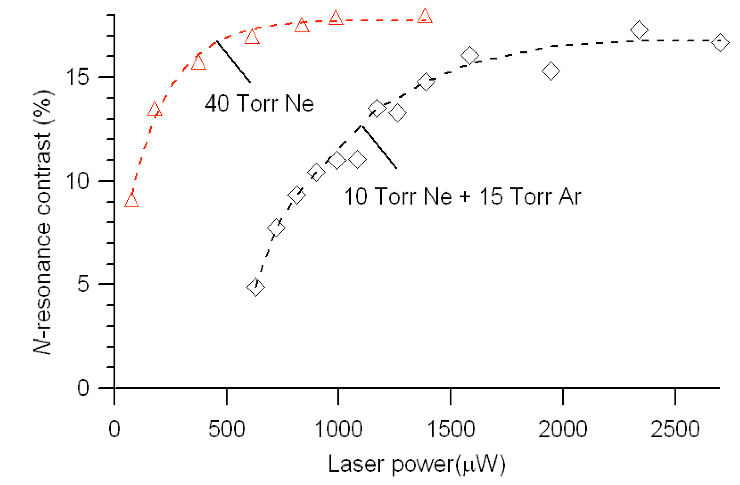


Laser power dependence

linewidth

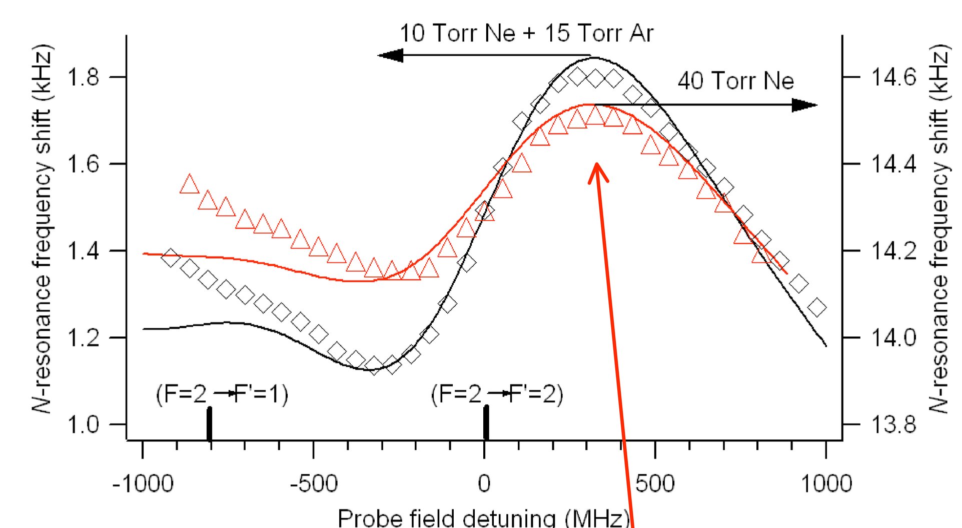


contrast



Performance improves at high buffer gas pressures

Light-shift measurements

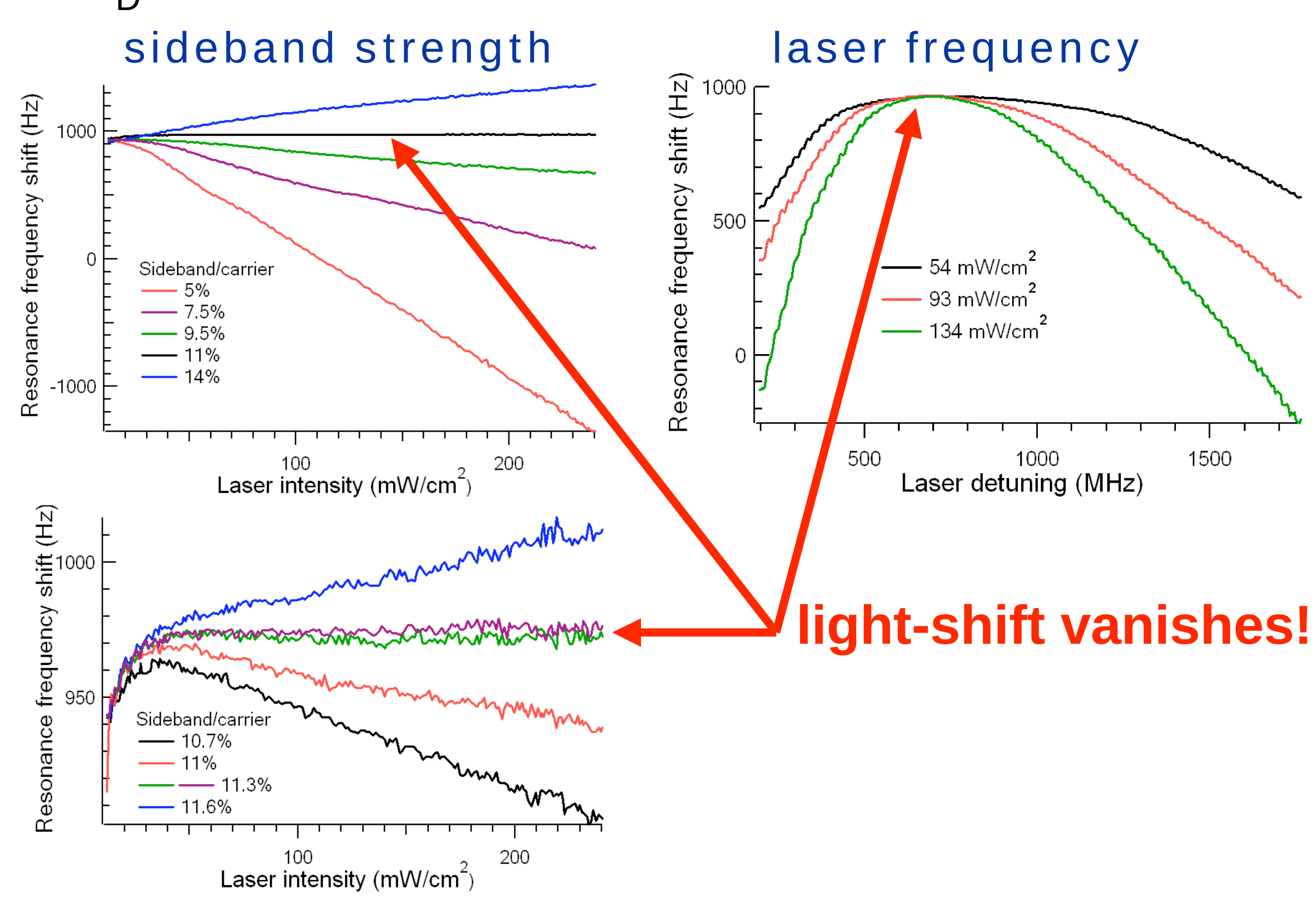


Analytical modeling:

Near the maximum:

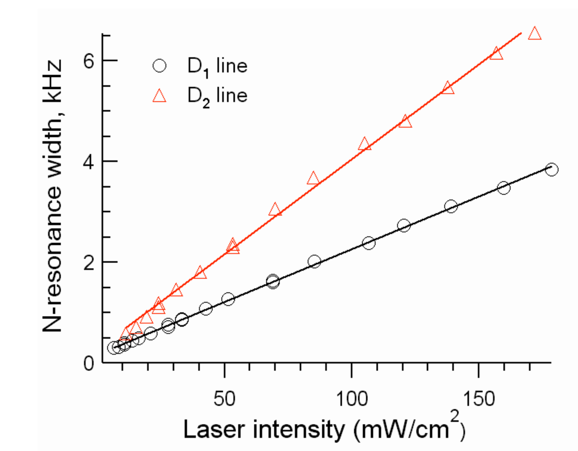
$$\delta \approx -\frac{\Omega_D^2}{2\nu_0} + \frac{\Omega_P^2}{\gamma} - \frac{2\Omega_P^2}{\gamma^3}\left(\Delta - \frac{\gamma}{2}\right)^2 + \ldots$$

For laser detuning, $\Delta = \frac{\gamma}{2}$, and drive ratio, $\frac{\Omega_P^2}{\Omega_D^2} \approx \frac{\gamma}{2\Delta}$, light shift vanishes:

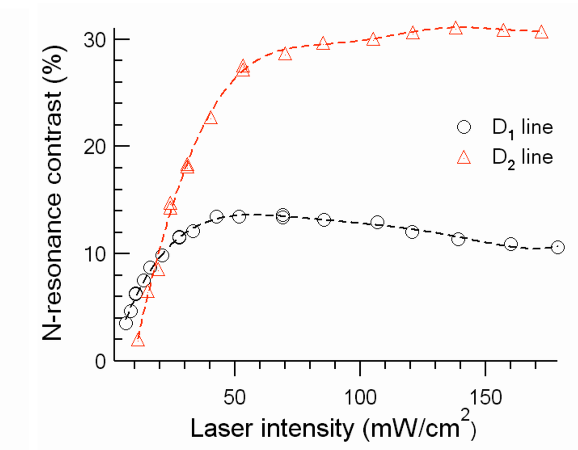


D_1 vs. D_2 comparison

linewidth



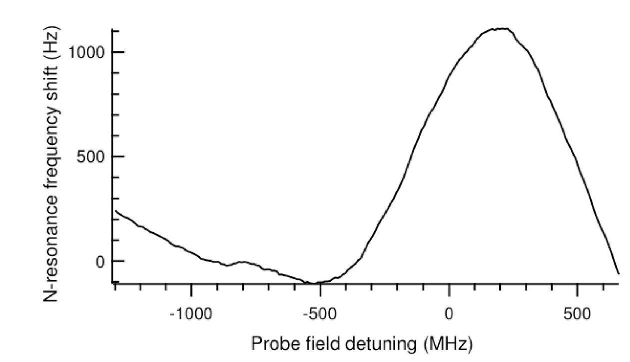
contrast



- *Higher contrast compensates for broader resonance*
- *Light shift compensation procedure also works of D_2*

Thin cell *N*-resonances studies

Diameter: 25 mm
Length: 1 mm
Buffer gas: 75 Torr Ne

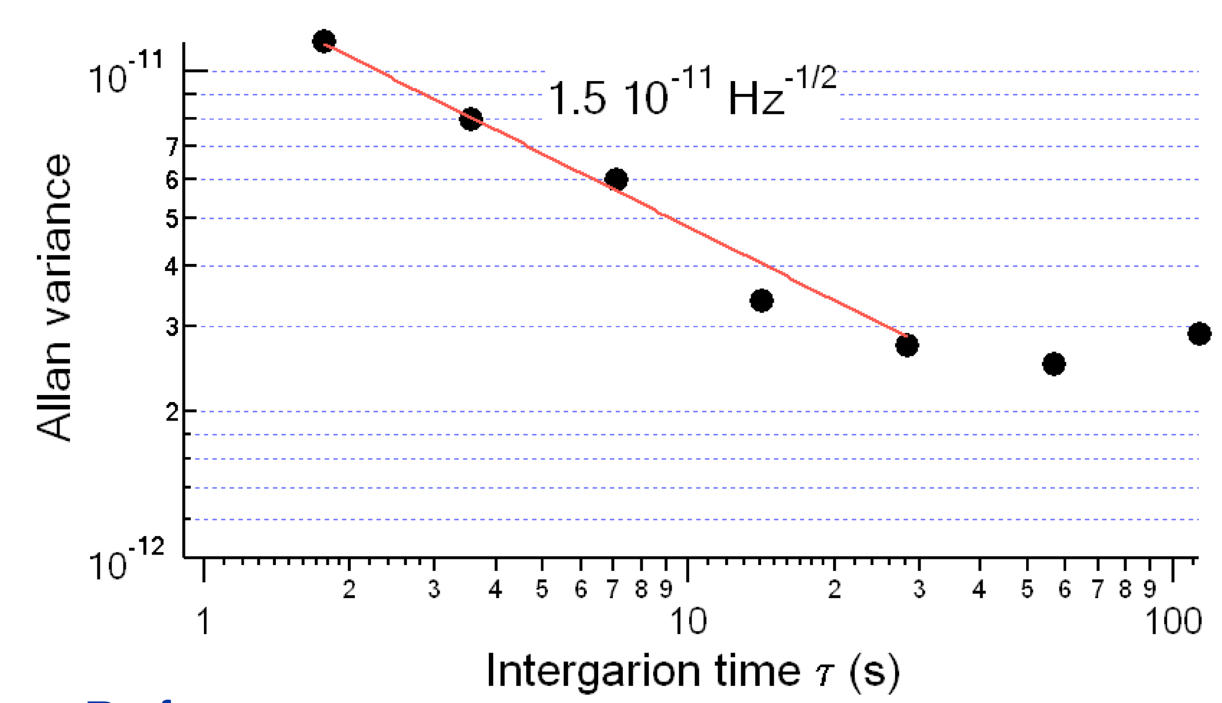


comparable to larger cells

Coherent population trapping vs. *N*-resonance

Reported light shifts :	CPT*	*N*-resonances
carrier field intensity:	~200 mHz/(μW/cm^2)	~0.01 mHz/(μW/cm^2)
carrier field frequency:	~1-10 mHz/MHz	~0.4 mHz/MHz^2
contrast	4	12
linewidth (Hz)	400	800

* Merimaa *et al.*, *J. Opt. Soc. B.* **20**, 73 (2003).



References

A.S. Zibrov *et al.*, "Observation of a three-photon electromagnetically induced transparency in hot atomic vapor," Phys. Rev. A **65**, 043817 (2002).
S. Zibrov et al., "A novel absorption resonance for all-optical atomic clocks," E-archive physics/0501090 (2005).