**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 ($\Omega_p$) and drive field ($\Omega_0$) have a difference frequency equal to the hyperfine frequency ($\nu_0$) an absorption resonance is observed.

### Experimental setup

- Rb cell inside magnetic shielding
- Fabry-Perot etalon
- Frequency synthesizer
- Slow frequency modulation
- Lock-in amplifier
- VCXO
- PID controller
- Frequency counter
- from hydrogen maser
- 6.835GHz frequency synthesizer
- EOM
- Laser
- Solenoid
- 6.835GHz
- Frequency synthesizer
- 87Rb level diagram
- $F=2$
- $F=1$
- $\nu_0 = 6.8 \text{ GHz}$
- $\Omega_p$
- $\Omega_0$
- $\nu_0$
- $\nu = \nu_0 + \Delta$
- Modulated laser spectrum

### Laser power dependence

- **linewidth**
- **contrast**

### Light-shift measurements

- Performance improves at high buffer gas pressures

### Analytical modeling:

Near the maximum:

$$\delta = -\frac{\Omega_p^2}{2\nu_0} + \frac{\Omega_0^2}{\gamma} - \frac{2\Omega_p^2}{\gamma^3} \left(\frac{\Delta - \gamma}{2}\right)^2 + \ldots$$

For laser detuning, $\Delta = \frac{\gamma}{2}$, and drive ratio, $\frac{\Omega_p^2}{\Omega_0^2} = \frac{\gamma}{2\Delta}$, light shift vanishes:

### Coherent population trapping vs. N-resonance

<table>
<thead>
<tr>
<th></th>
<th>CPT*</th>
<th>N-resonances</th>
</tr>
</thead>
<tbody>
<tr>
<td>carrier field intensity</td>
<td>~200 mHz/($\mu$W/cm²)</td>
<td>~0.01 mHz/($\mu$W/cm²)</td>
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<tr>
<td>carrier field frequency</td>
<td>~1-10 mHz/MHz²</td>
<td>~0.4 mHz/MHz²</td>
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<tr>
<td>contrast</td>
<td>4</td>
<td>12</td>
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<tr>
<td>linewidth (Hz)</td>
<td>400</td>
<td>800</td>
</tr>
</tbody>
</table>


### References