Tuning laser intracavity dispersion: switching from vibration insensitive laser to the cavity length enhanced sensitivity.

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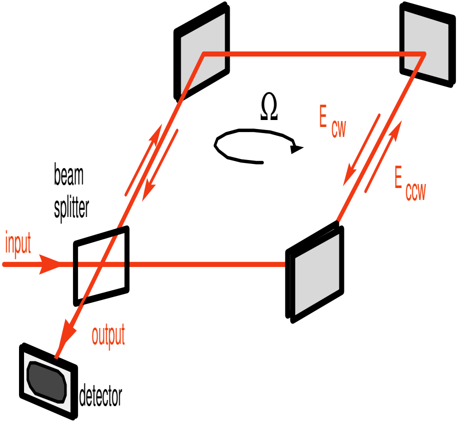
William & Mary
CHARTERED 1693

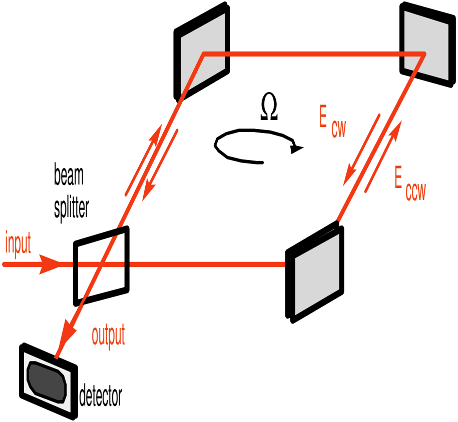
SPIE, 2 February 2019

Dispersive cavity response



$$\Delta f = f_0 \frac{\Delta L}{L}$$

Dispersive cavity response



$$\Delta f = f_0 \frac{\Delta L}{L} \frac{1}{n_g} = \Delta f_{empty} \frac{1}{n_g}$$

Group index

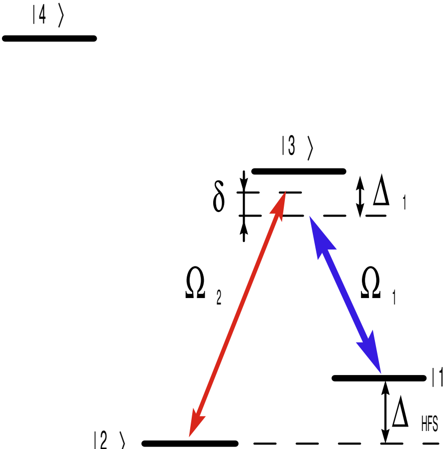
$$n_g(f) = n + f_0 \frac{\partial n}{\partial f}$$

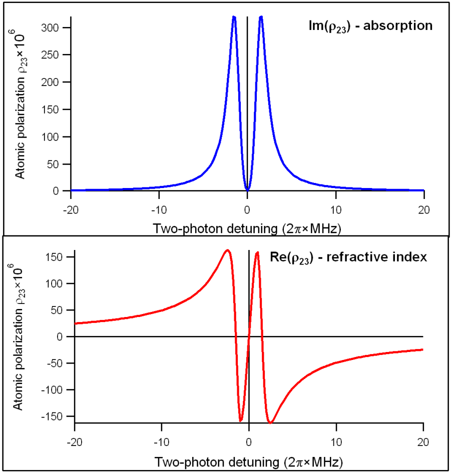
$$v_g = c/n_g$$

Cavity response enhanced if $n_g < 1$ i.e. under the fast light condition

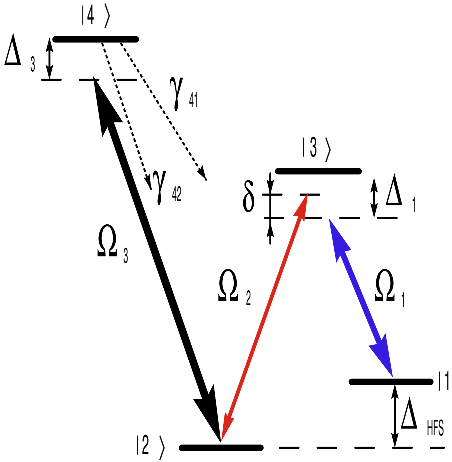
Shahriar et al., PRA **75**, 053807 (2007)

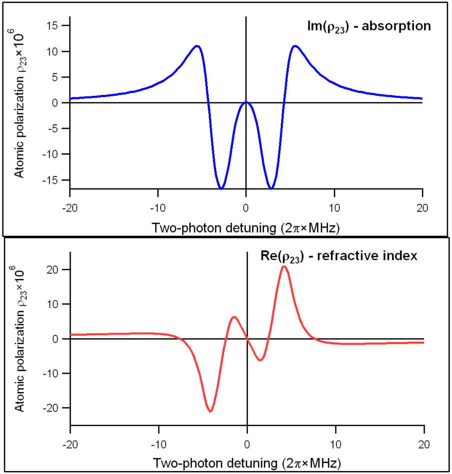
EIT - slow light





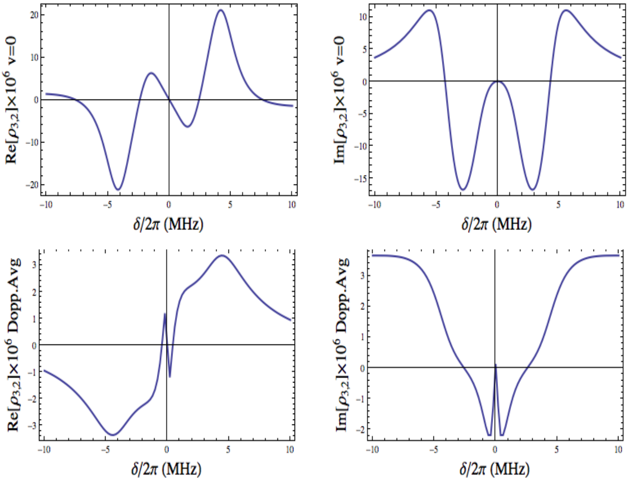
N-bar with four-wave mixing - fast and with gain





N-bar with Doppler averaging

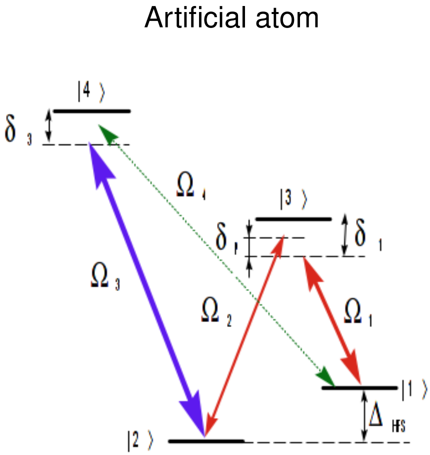
Refractive index | Absorption

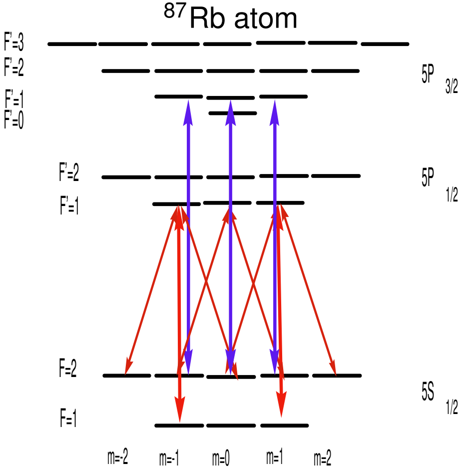


Stationary atoms

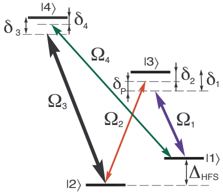
Room temperature
Doppler averaged

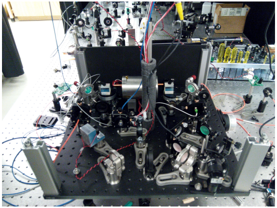
N-bar levels and fields diagram

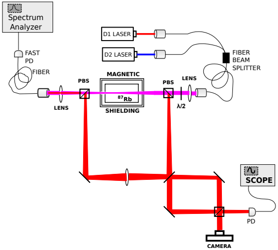




Setup and measured pulling factor

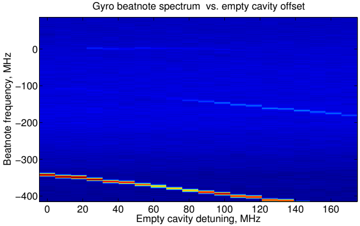


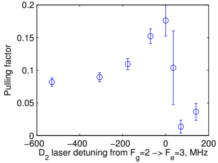




$$P.F. = \frac{\Delta f_{\text{dispersive}}}{\Delta f_{\text{empty}}} = \frac{1}{n_g}$$

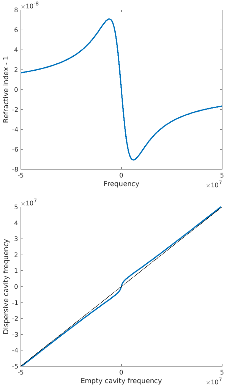
$$\Delta f_{\text{empty}} = f_0 \frac{\Delta L}{L}$$





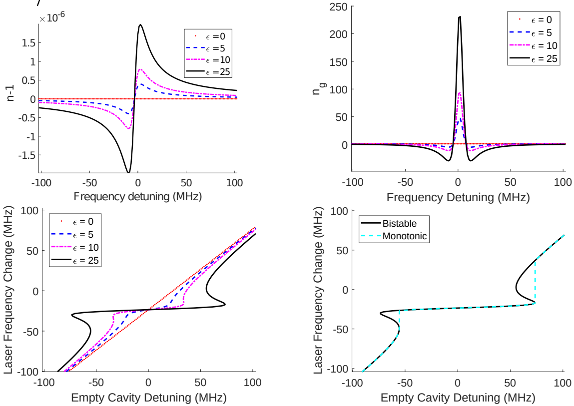
Fast

$dn/d\omega < 1$



Slow

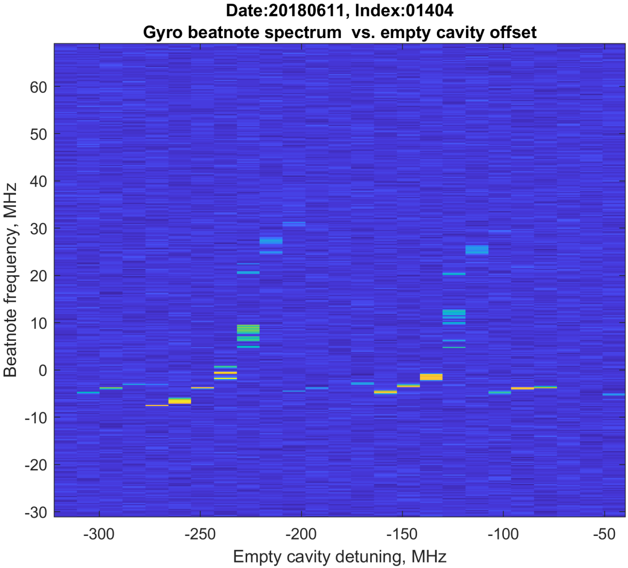
$dn/d\omega > 1$



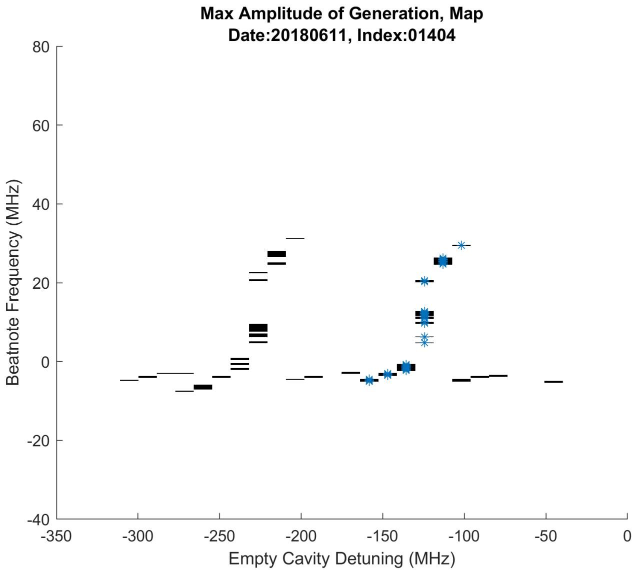
Lasing equation

$$n(\omega)L = m\lambda = mc\frac{2\pi}{\omega}$$

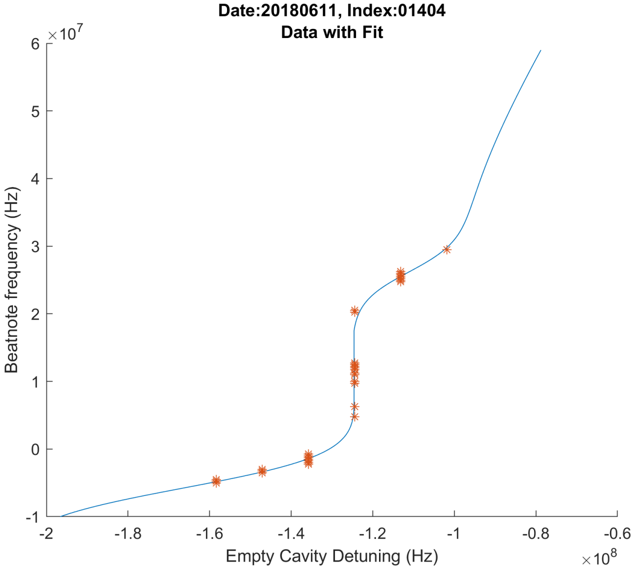
Beatnote map with “high” pulling factor



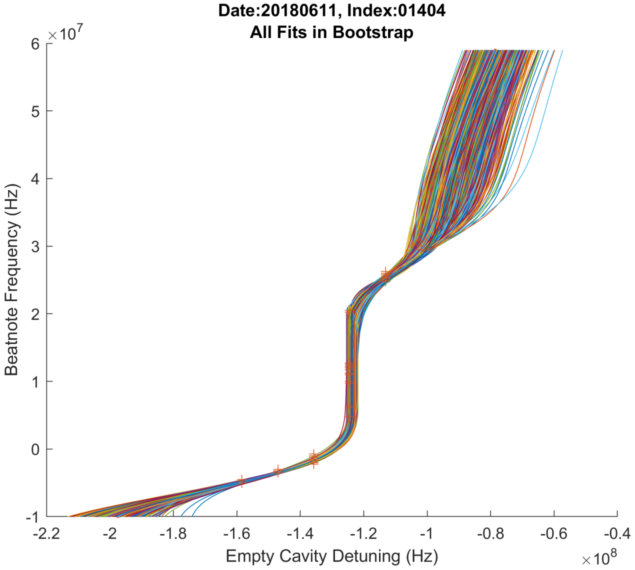
Beatnote map with “high” pulling factor



Beatnote map with “high” pulling factor

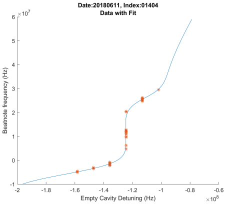


Beatnote map with “high” pulling factor

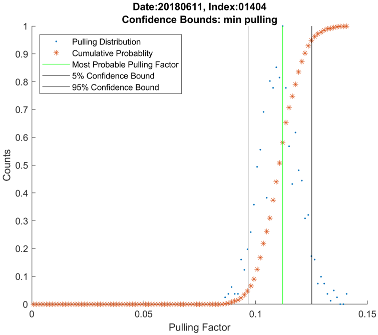


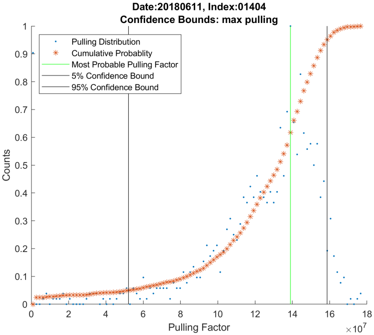
Confidence in “high” and “low” pulling factors

Low PF$= 0.112$
with 90% bounds
$(0.096, 0.125)$

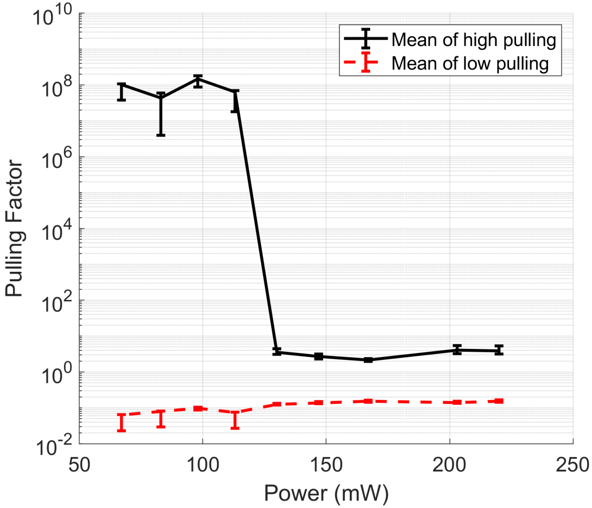


High PF$= 120 \times 10^6$
with 90% bounds
$(52 \times 10^6, 158 \times 10^6)$

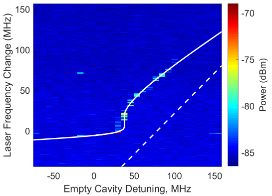




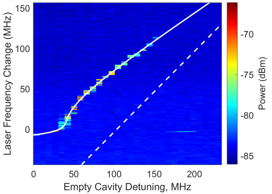
Temperature 100°C, $\text{Power}_{D1}/\text{Power}_{D2} = 3/2$



Power 98 mW

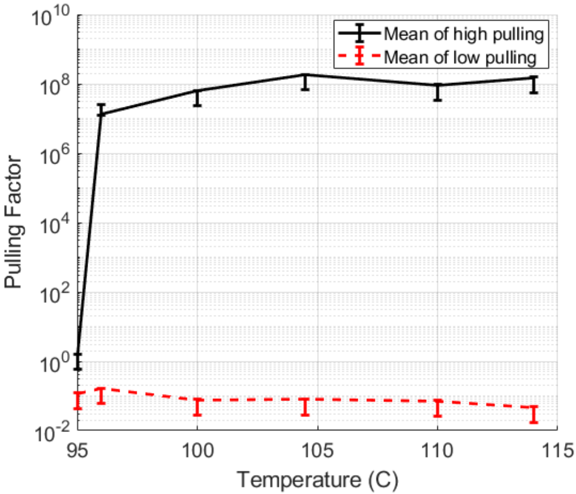


Power 147 mW

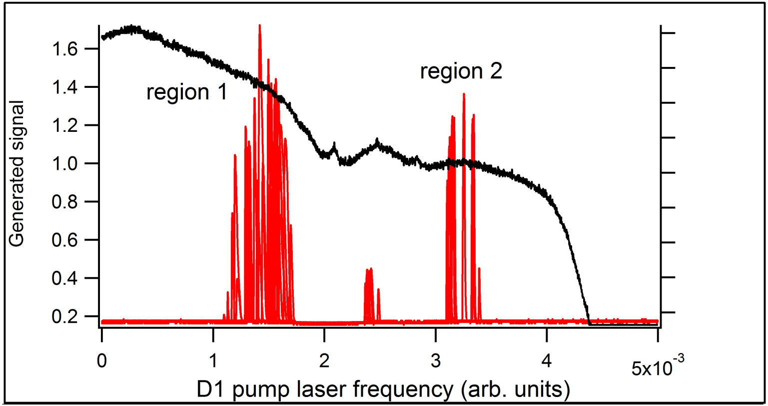


Pulling factor vs temperature

Total power 82 mW, $\text{Power}_{D1}/\text{Power}_{D2} = 2/1$

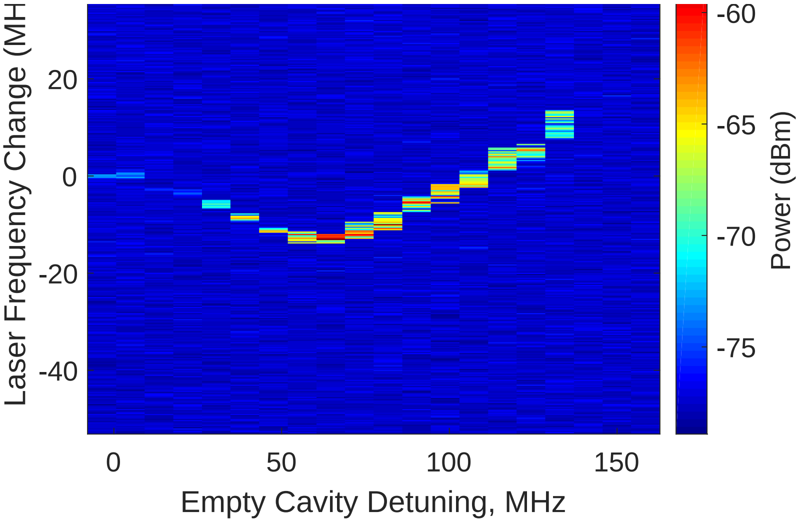


Pulling factor vs detuning dependence

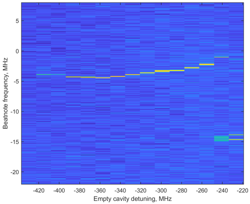


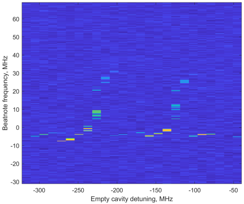
- Region 1: Pulling factor ≤ 1 (no discontinuities), high laser output
- Region 2: Large pulling $\gg 1$
- Region 3 (middle): vibration free regime

Laser insensitivity to cavity motion

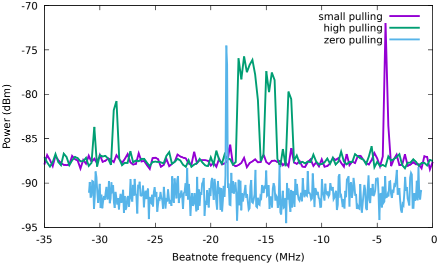


Beatnotes width comparison





Quantum linewidth $\sim 1/n_g^2 = (P.F.)^2$

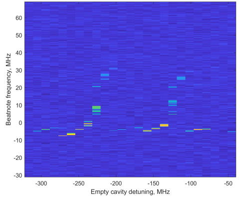


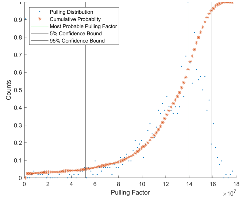
Vibrations-broadened linewidth $\sim 1/n_g = P.F.$

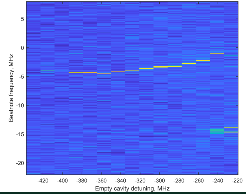
C. Henry, IEEE Journal of Quantum Electronics 18, 259 (1982).

People

Summary







- We obtained enhanced cavity response as high 10^8 and potentially reached ∞
- Under certain condition the laser output does not depend on cavity length, i.e. we have vibration insensitive laser

Savannah L. Cuozzo, Eugeniy E. Mikhailov, "Dispersion enhanced laser frequency sensitivity and stability", arXiv:1812.08260, (2018).

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