Vibration free laser via change of the cavity pulling sign.

Eugeniy E. Mikhailov, Savannah Cuozzo, Demetrious T. Kutzke,
Owen Wolfe, Irina Novikova[1],
Simon Rochester, Dmitry Budker[2],

1

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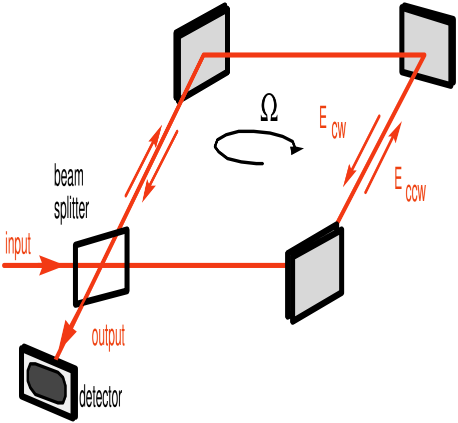
2

Rochester Scientific

Photonics West, 01 February 2018

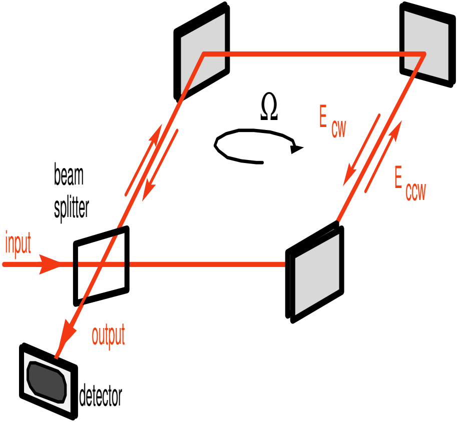
Sagnac effect and cavity response



$$\Delta p = \pm \Omega R t = \pm \frac{2 A \Omega}{c}$$

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

Sagnac effect and cavity response



$$\Delta p = \pm \Omega R t = \pm \frac{2A\Omega}{c}$$

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

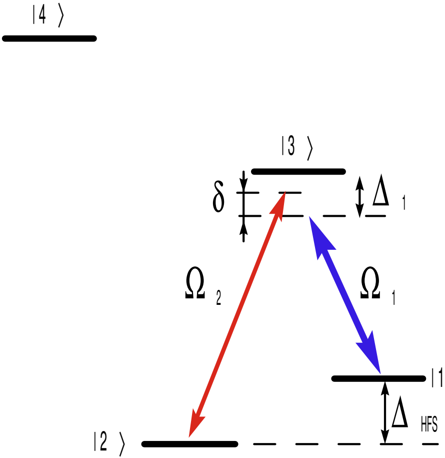
Group index

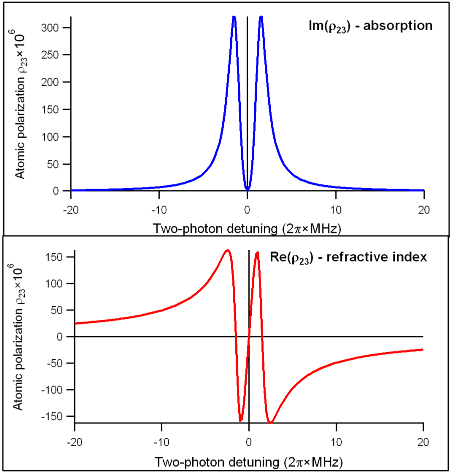
$$n_g(f) = n + f_0 \frac{\partial n}{\partial f}$$

$$v_g = c / n_g$$

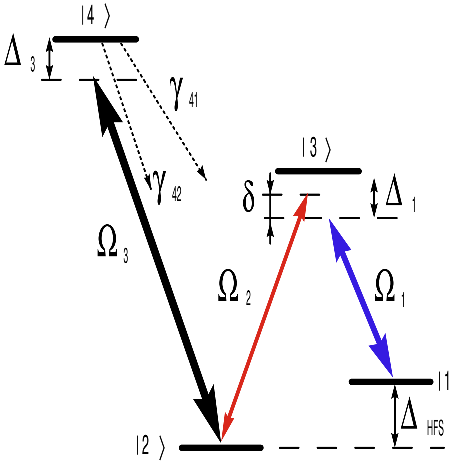
Cavity response enhanced if $n_g < 1$ i.e. under the fast light condition
Shahriar et al., PRA **75**, 053807 (2007)

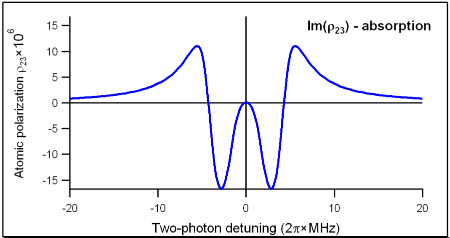
EIT - slow light

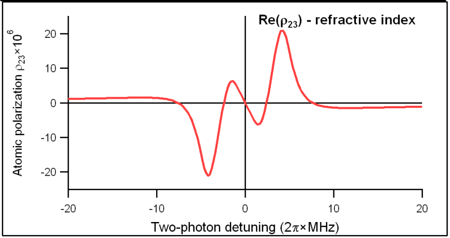




N-bar with four-wave mixing - fast and with gain



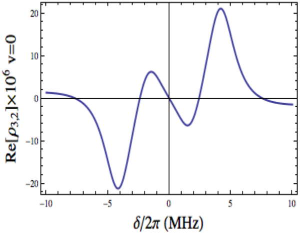


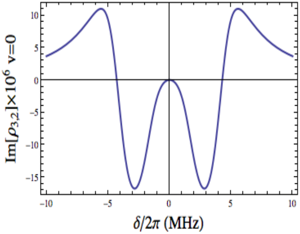


N-bar with Doppler averaging

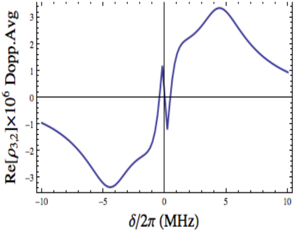
Refractive index

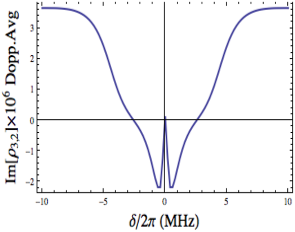
Absorption





Stationary atoms

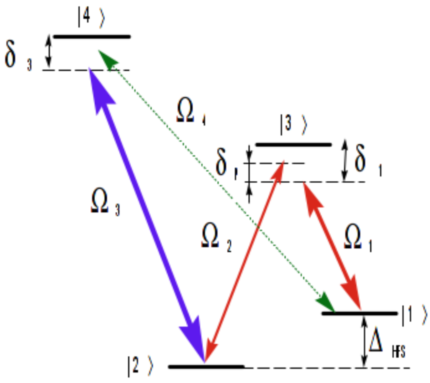




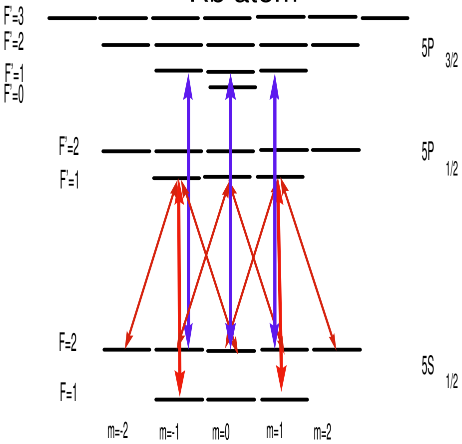
Room temperature
Doppler averaged

N-bar levels and fields diagram

Artificial atom

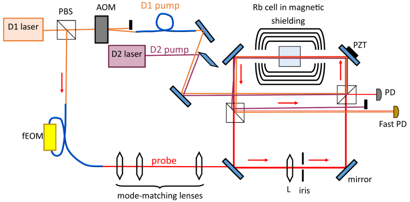


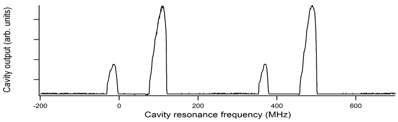
^{87}Rb atom

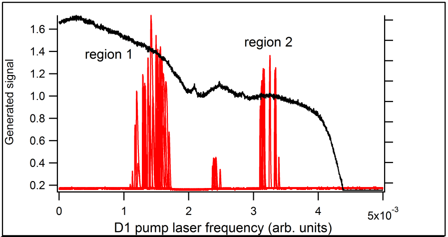


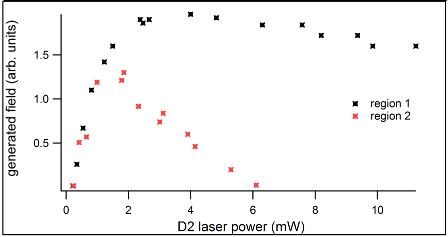
The first gyro setup and its performance

D_1 tuned around $F_g = 1 \to F_e = 1, 2$





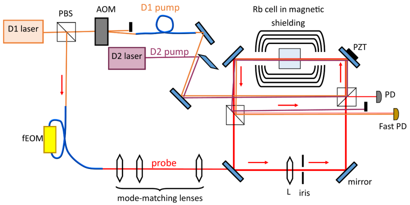


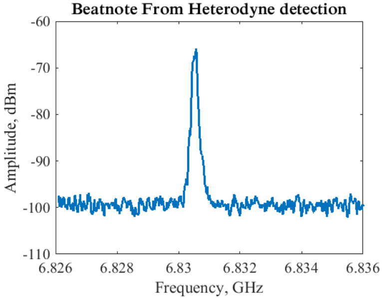


Finesse = 20

E. Mikhailov, *et al.* Optical Engineering, Issue 10, 53, 102709, (2014)

The first gyro setup and its performance

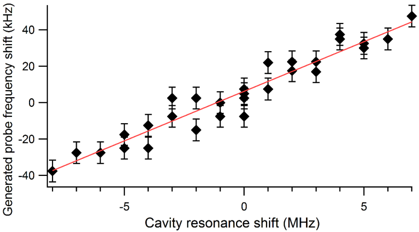




$$P.F. = \frac{\Delta f_{\text{dispersive}}}{\Delta f_{\text{empty}}} = \frac{1}{n_g}$$

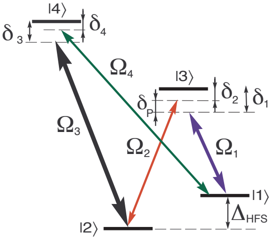
$$\Delta f_{\text{empty}} = f_0 \frac{\Delta p}{p}$$

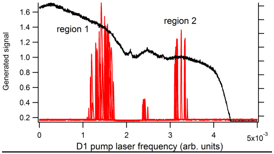
Finesse = 20 $\rightarrow$ Pulling $1/200$

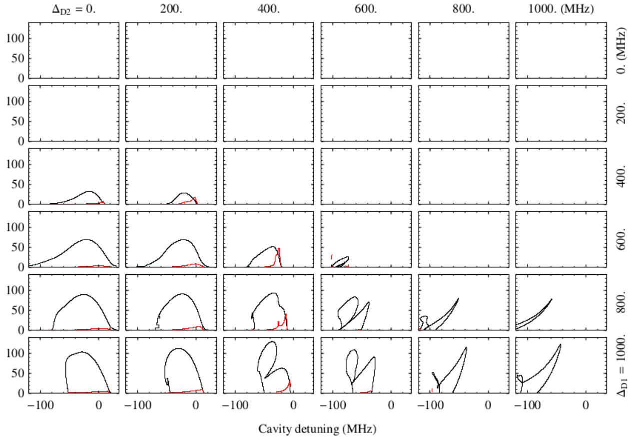


E. Mikhailov, *et al.* Optical Engineering, Issue 10, 53, 102709, (2014)

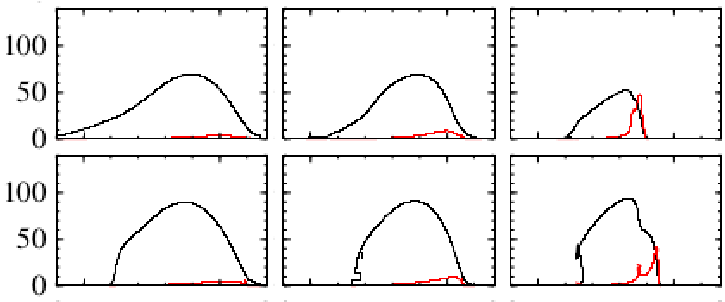
Gyro lasing: theory vs. experiment



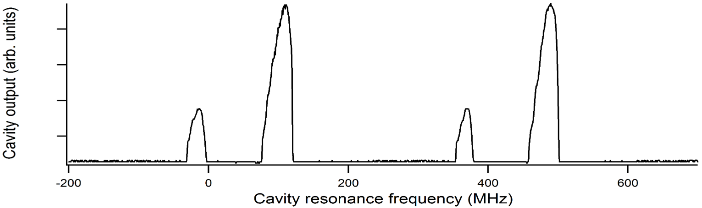




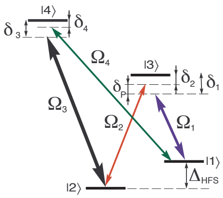
Gyro pulling and amplitude vs. gyro cavity detuning

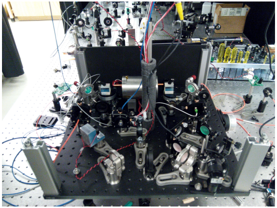


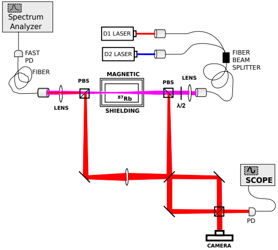
Cavity detuning span 150 MHz. Pulling $\times 100$



Pulling factor with increased cavity finesse (20 → 70)







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

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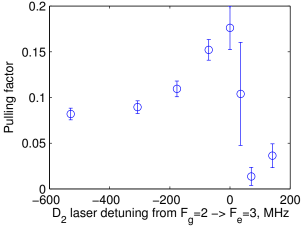
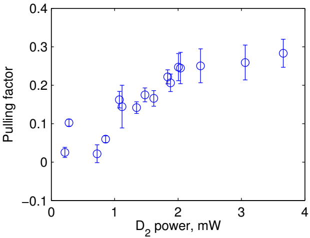
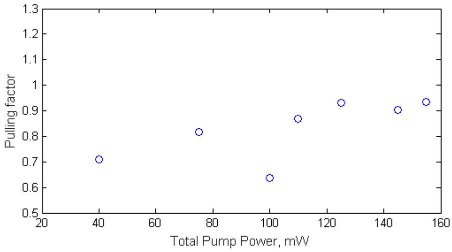
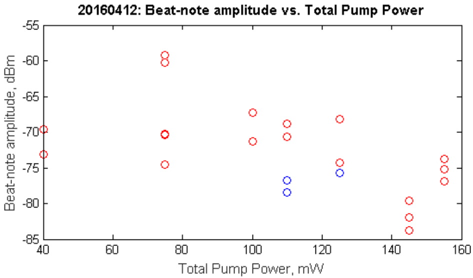


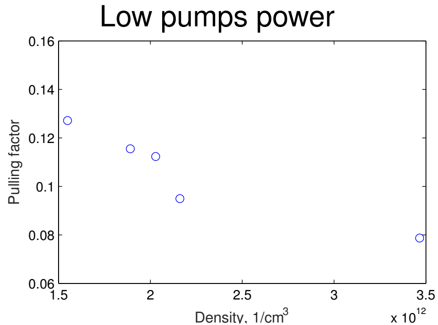


Dependence on total pumps power





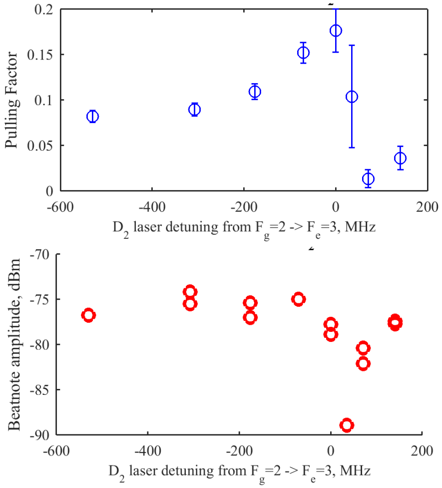
Dependence on ^{87}Rb vapor density



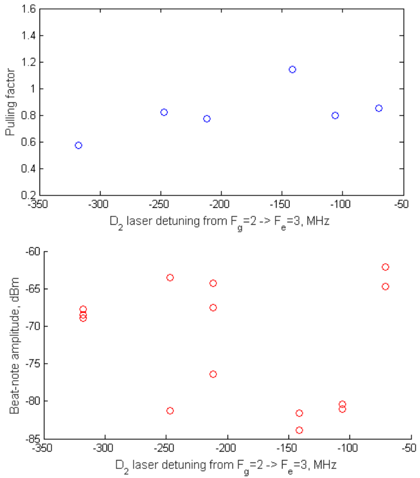
Demetrious T. Kutzke, Owen Wolfe, Simon M. Rochester, Dmitry Budker, Irina Novikova, Eugeniy E. Mikhailov, "Tailorable dispersion in a four-wave mixing laser", Optics Letters, Issue 14, 42, 2846, (2017).

High power regime: dependence on D_2 detuning

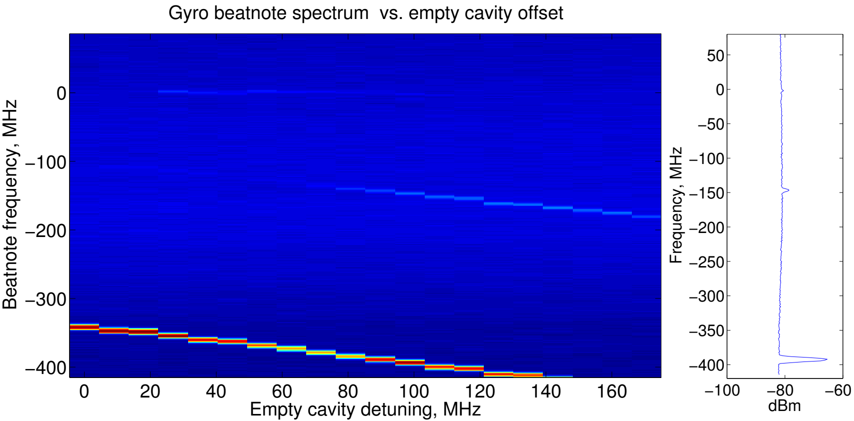
Pumps power ≈ 6 mW



Pumps power ≈ 180 mW

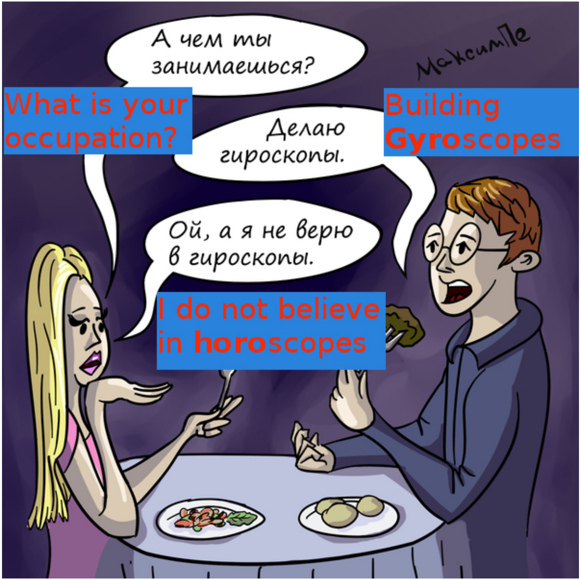


Gyroscope laser multi-mode structure

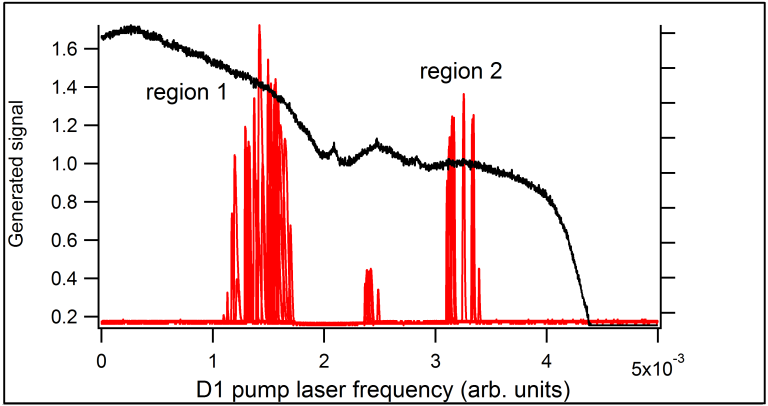


Cell temperature 110°C, total power 350 mW.
Modes pulling factors are 0.54, 0.45, 0.04.

I do not believe in horoscopes

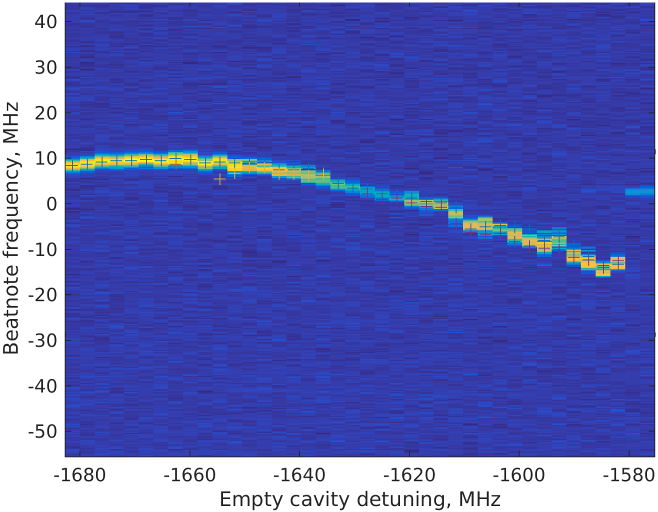


Do you remember region 3?



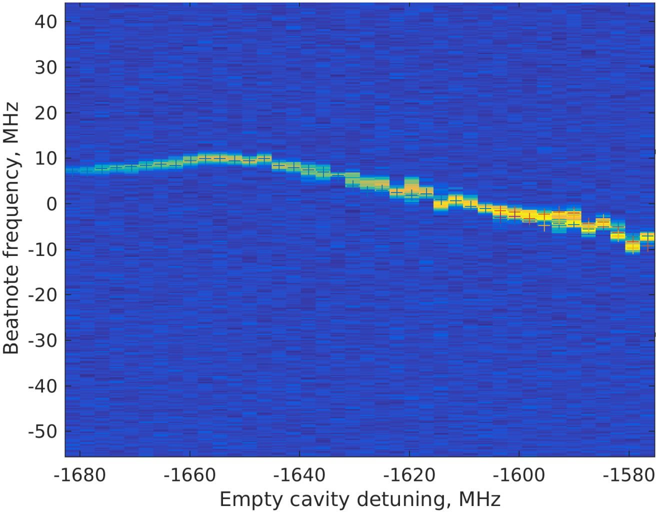
Laser independence on cavity detuning

Pumps power $\approx$ 60 mW, cell temperature 100 ^oC



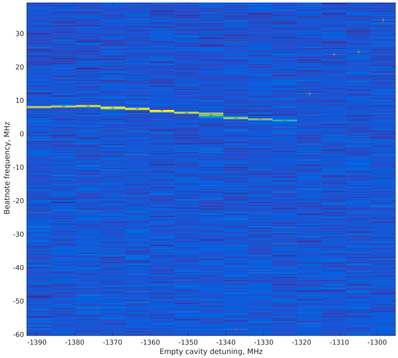
Laser independence on cavity detuning

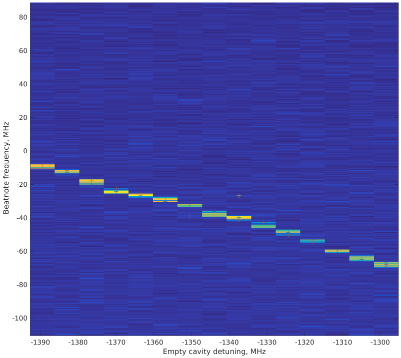
Pumps power ≈ 60 mW, cell temperature 100 ^{o}C



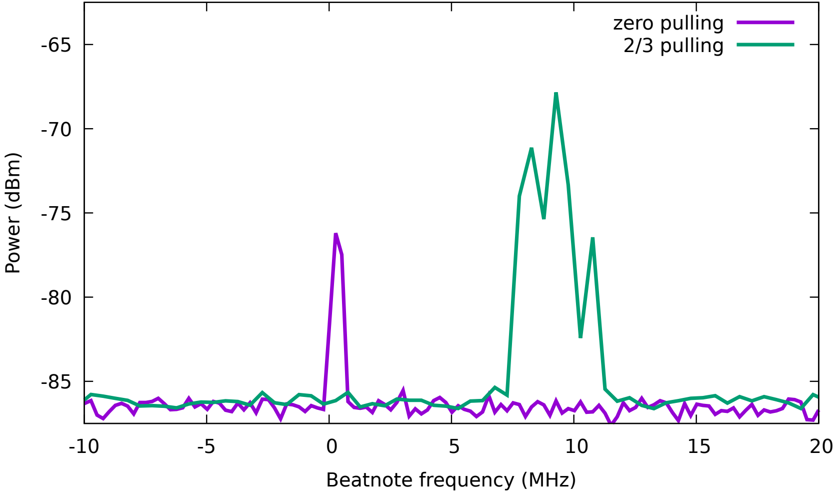
Comparison: no pulling and high pulling regimes

Pumps power 38 mW, $\approx$ 360 mW, cell temperature 102 ^{o}C Most importantly different D1 detunings.





Beatnotes width comparison

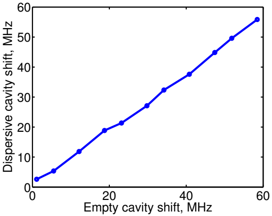


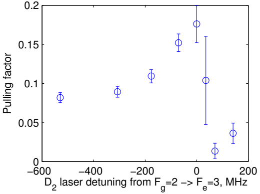
Do we have lasing linewidth narrowing by $1/n_g^2$?

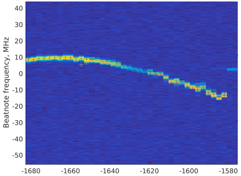
People

Irina Novikova, Owen Wolfe, Demetrious Kutzke, Savannah Cuozzo (WM),
Dmitry Budker, Simon Rochester (Rochester Scientific).

Summary







- Improved puling factor: $0.005 \rightarrow 0.3$ with increased finesse ($20 \rightarrow 70$)
- Increased pump lasers power (6 mW $\rightarrow$ 200 mW) pushed the pulling factor to 1
- Setup has widely tunable response influenced by
  - pump lasers power and detuning
  - density of ^{87}Rb atoms
  - cavity finesse
- Under certain condition the laser output does not depend on cavity length

We are grateful for financial support to
NAVAIR