Towards active gyroscope in the fast-light regime.

Eugeniy E. Mikhailov, Owen Wolfe, Irina Novikova[1],
Simon Rochester, Dmitry Budker[2],

1
WILLIAM & MARY
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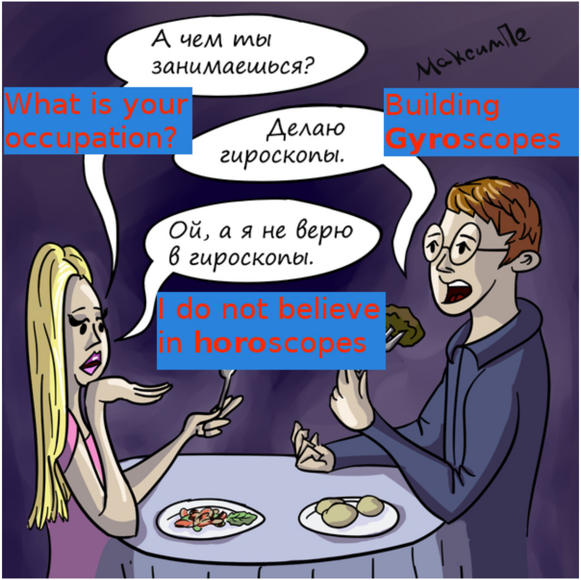
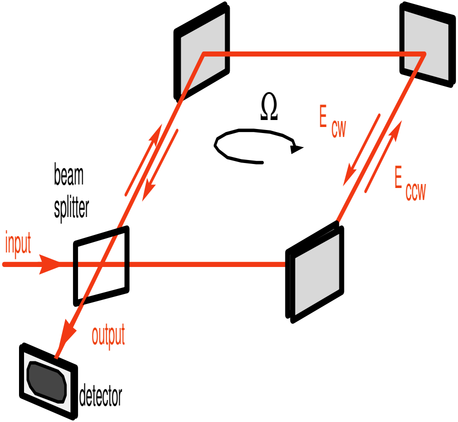
Rochester Scientific

LPHYS, 14 July 2016

I do not believe in horoscopes



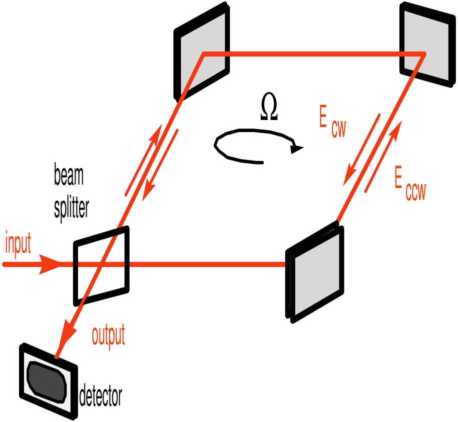
Sagnac effect and cavity response



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

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

Sagnac effect and cavity response



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

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

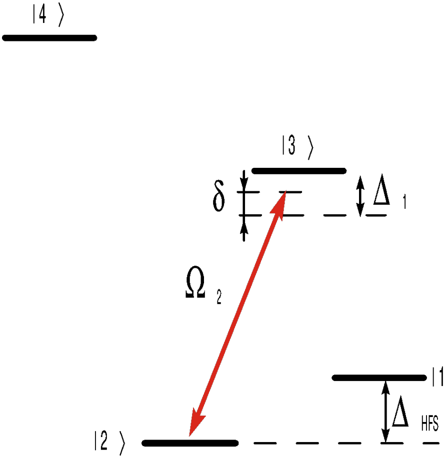
Group index

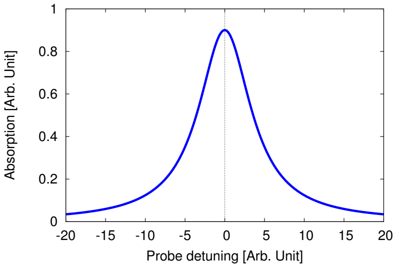
$$n_g(f) = n + f_0 \frac{\partial n}{\partial f}$$

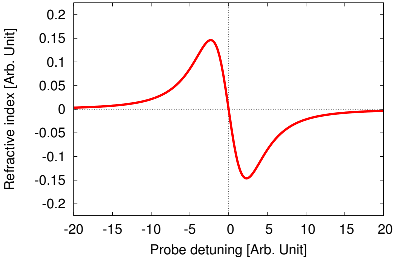
$$v_g = c/n_g$$

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

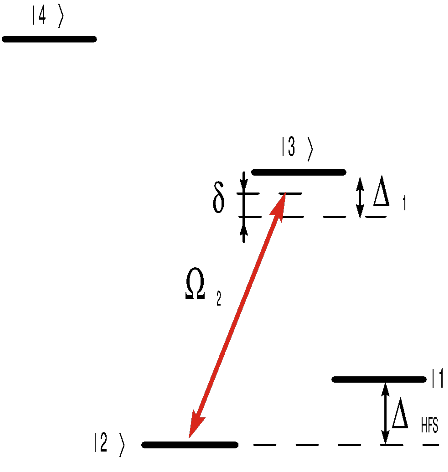
Absorption line - fast light

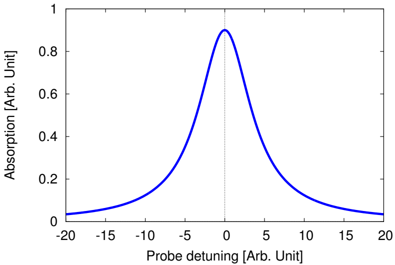


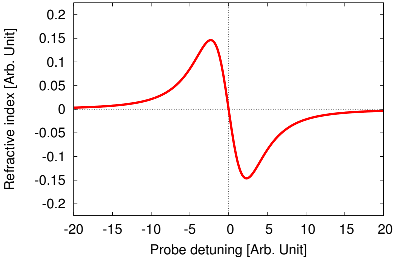




Absorption line - fast light

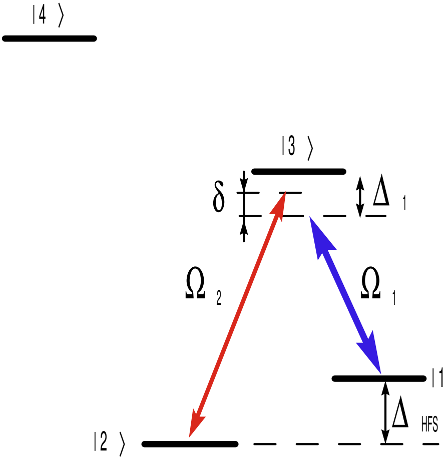


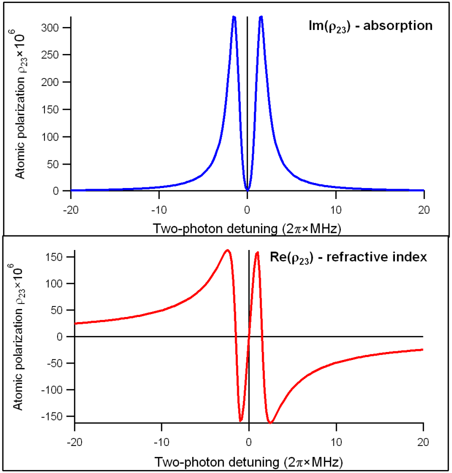




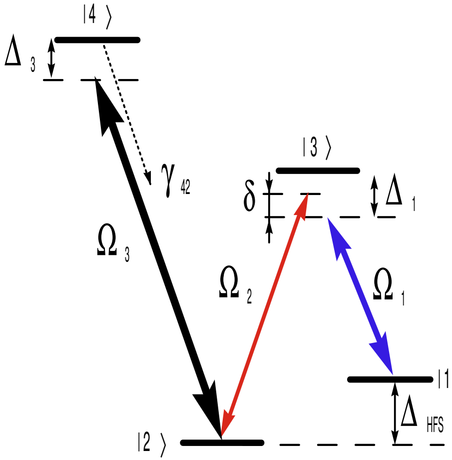
6 time enhancement
by David Smith et al.

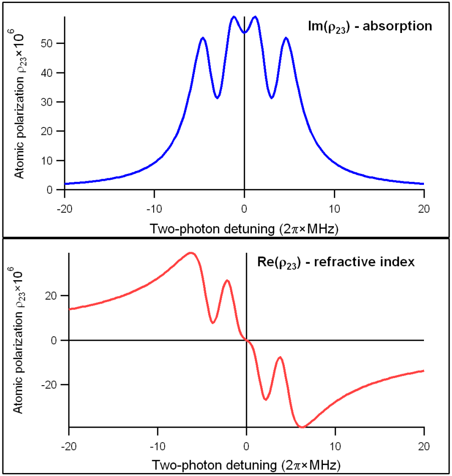
EIT - slow light



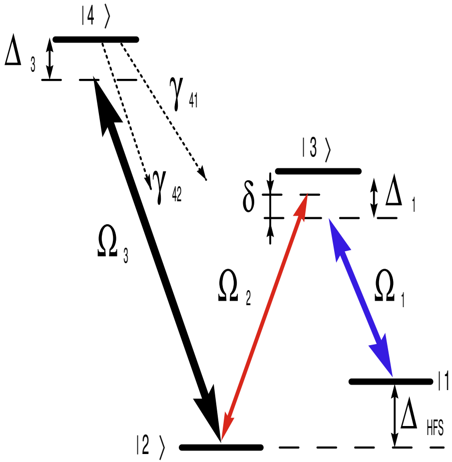


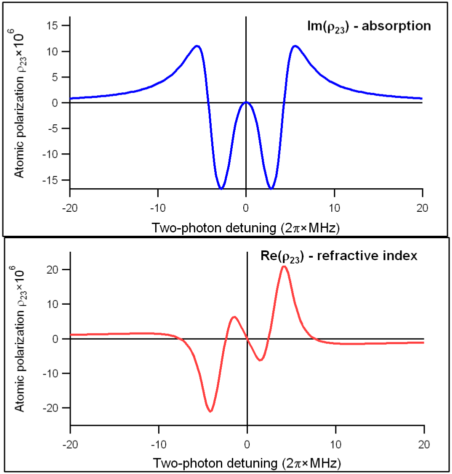
N-scheme, with forbidden transition - fast but no gain





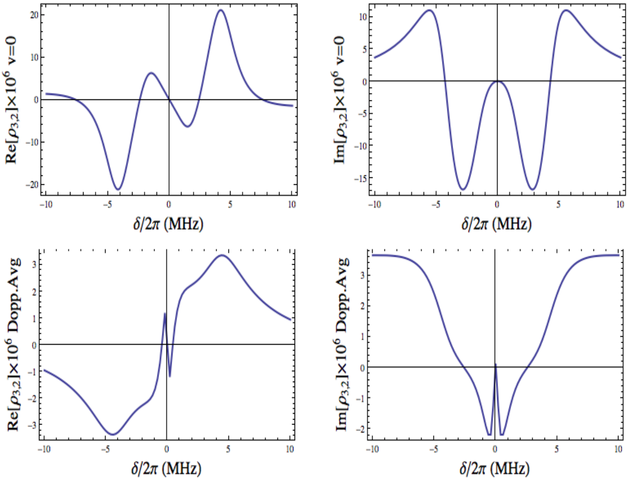
N-bar with four-wave mixing - fast and with gain





N-bar with Doppler averaging

Refractive index | Absorption

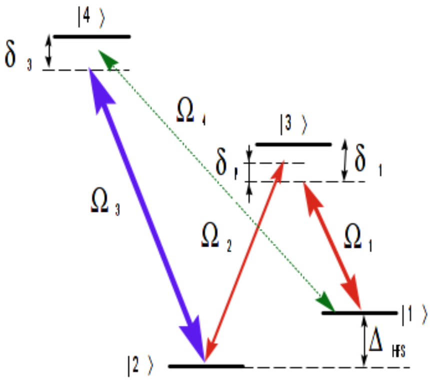


Stationary atoms

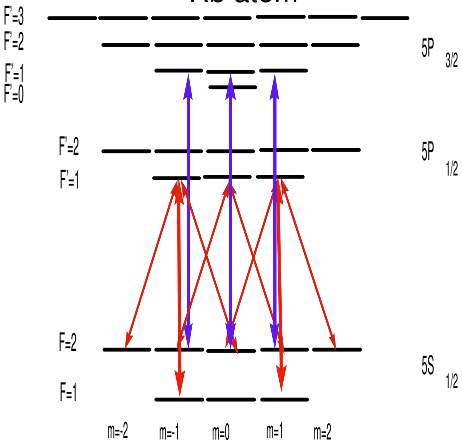
Room temperature
Doppler averaged

N-bar levels and fields diagram

Artificial atom

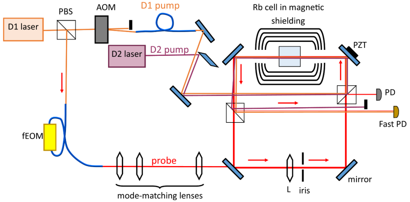


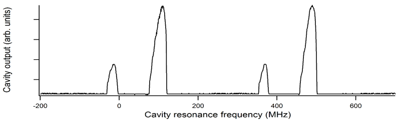
^{87}Rb atom



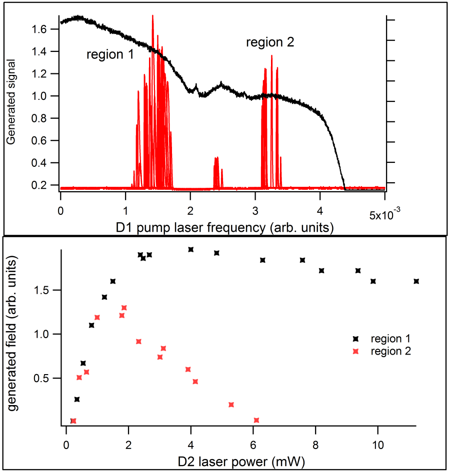
The first gyro setup and its performance

D$_1$ tuned around $F_g = 1 \rightarrow F_e = 1, 2$



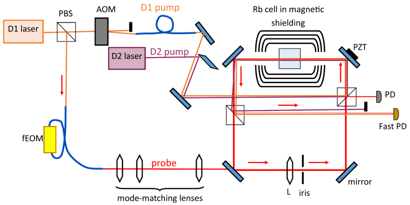


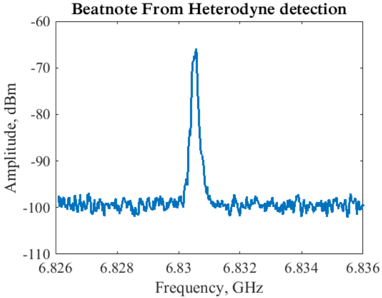
Finesse = 20



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

The first gyro setup and its performance

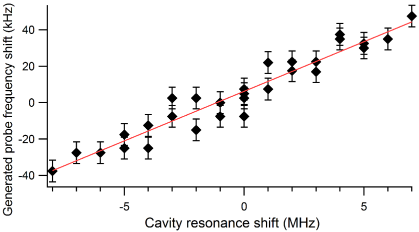




$$P.F. = \frac{\Delta f_{\text{dispersive}}}{\Delta f_{\text{empty}}} = \frac{1}{n_g}$$

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

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



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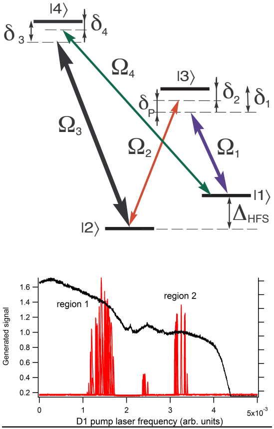
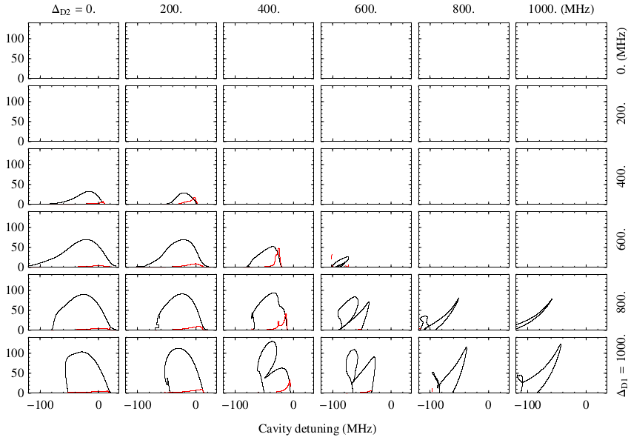
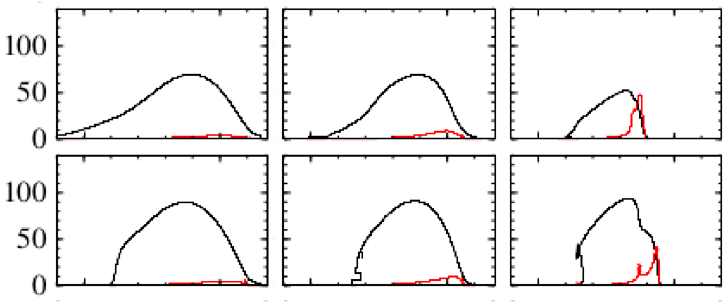
Gyro lasing: theory vs. experiment

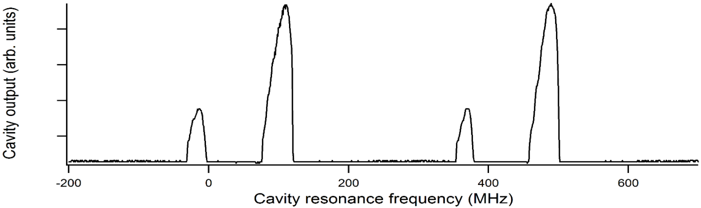




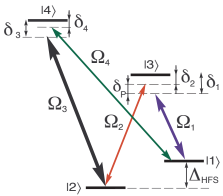
Gyro pulling and amplitude vs. gyro cavity detuning

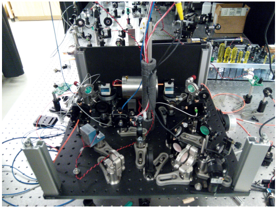


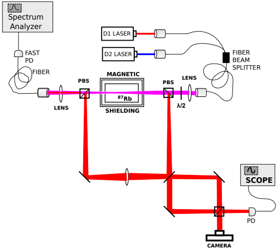
Cavity detuning span 150 MHz. Pulling ×100



Pulling factor with increased cavity finesse (20 $\rightarrow$ 70)







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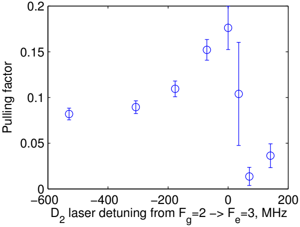
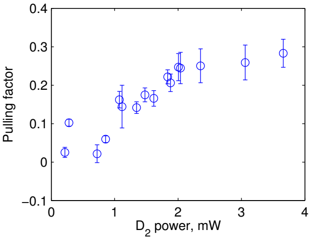
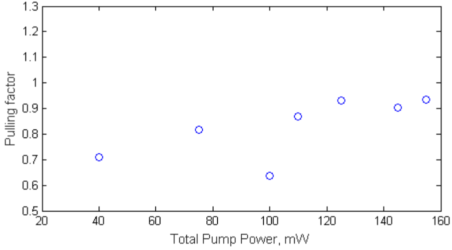
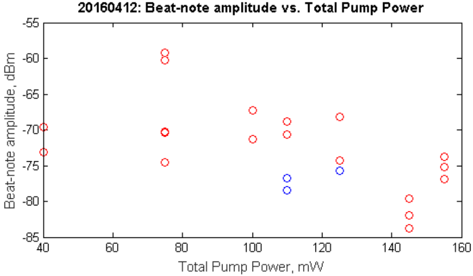
$$\Delta f_{\text{empty}} = f_0 \frac{\Delta p}{p}$$



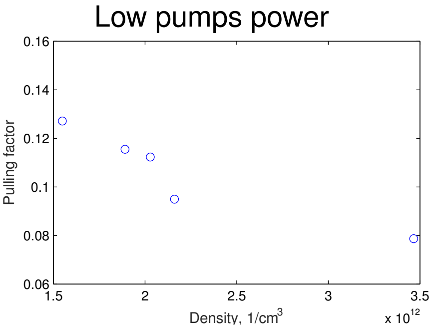


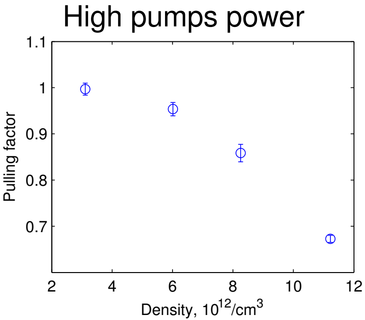
Dependence on total pumps power



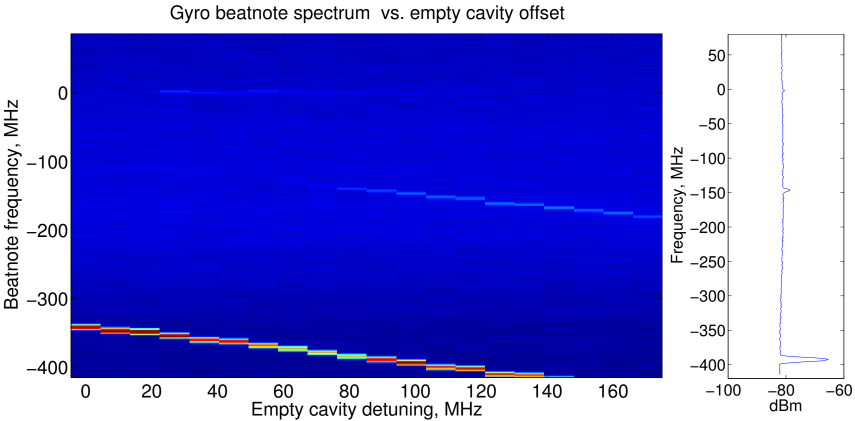


Dependence on ^{87}Rb vapor density





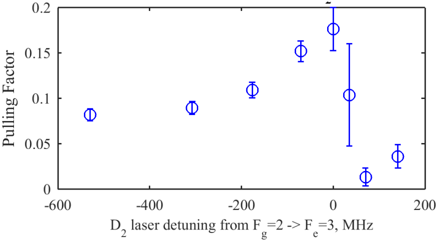
Gyroscope laser multi-mode structure

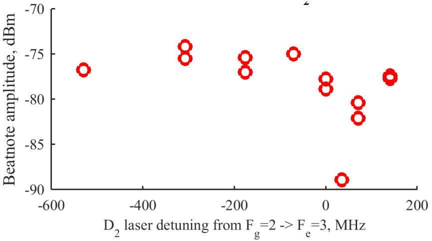


Cell temperature 110°C, total power 350 mW.
Modes pulling factors are 0.54, 0.45, 0.04.

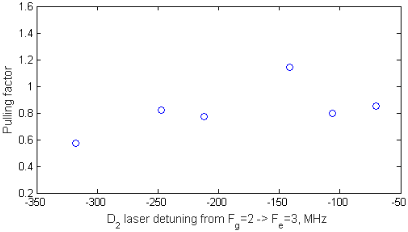
High power regime: dependence on D_2 detuning

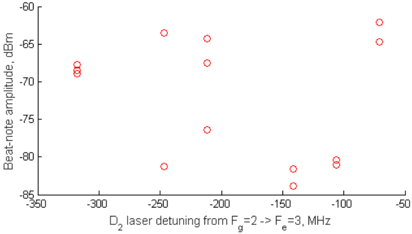
Pumps power ≈ 6 mW





Pumps power ≈ 180 mW

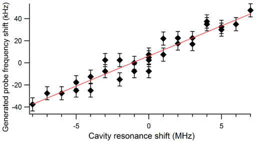


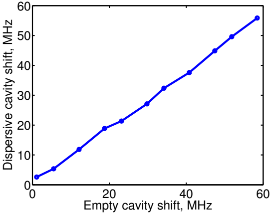


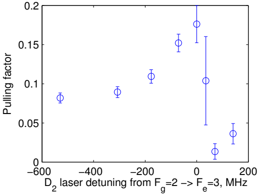
People

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

Summary







- Improved puling factor: 0.005 $\to$ 0.3 with increased finesse (20 $\to$ 70)
- Increased pump lasers power (6 mW $\to$ 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
- This allows us to tune the response of the system on demand

We are grateful for financial support to
NAVAIR