Active optical gyroscope with controllable dispersion.

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\textsuperscript{1}LPHYS, 14 July 2016

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Sagnac effect and cavity response

\[ \Delta p = \pm \Omega Rt = \pm \frac{2A\Omega}{c} \]

\[ \Delta f = f_0 \frac{\Delta p}{p} \]

Towards fast gyroscope
Sagnac effect and cavity response

\[ \Delta p = \pm \Omega R \tau = \pm \frac{2\Delta \Omega}{c} \]

\[ \Delta f = f_0 \frac{\Delta p}{p} \frac{1}{n_g} = \Delta f_{\text{empty}} \frac{1}{n_g} \]

Group index

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

\[ v_g = \frac{c}{n_g} \]

Cavity response enhanced if \( n_g < 1 \) i.e. under the fast light condition
Shahriar et al., PRA 75, 053807 (2007)
N-bar with four-wave mixing - fast and with gain

\[ |1\rangle, |2\rangle, |3\rangle, |4\rangle, \delta, \Delta_{\text{HFS}} \]

\[ \Omega_1, \Omega_2, \Omega_3, \gamma_{41}, \gamma_{42} \]

\[ \text{Im}(\rho_{23}) - \text{absorption} \]

\[ \text{Re}(\rho_{23}) - \text{refractive index} \]

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N-bar with Doppler averaging

Refractive index

Absorption

Stationary atoms

Room temperature Doppler averaged
The first gyro setup and its performance

D₁ tuned around $F_g = 1 \rightarrow F_e = 1, 2$

Finesse = 20

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

Gyro lasing: theory vs. experiment

\[ \begin{align*}
|2\rangle & \rightarrow |1\rangle & \Delta \delta_4 \\
|3\rangle & \rightarrow |4\rangle & \Omega_1 \\
|4\rangle & \rightarrow |1\rangle & \Omega_2 \\
|1\rangle & \rightarrow |2\rangle & \Omega_3 \\
|1\rangle & \rightarrow |4\rangle & \Omega_4 \\
\end{align*} \]

\[ \Delta \delta_2 = 0, \ 200, \ 400, \ 600, \ 800, \ 1000 \ (\text{MHz}) \]

\[ \text{Cavity detuning (MHz)} \]
Gyro pulling and amplitude vs. gyro cavity detuning

Cavity detuning span 150 MHz. Pulling $\times 100$
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}
Dependence on total pumps power

![Graph showing the dependence of pulling factor on total pump power.](image1)

20160412: Beat-note amplitude vs. Total Pump Power

![Graph showing the beat-note amplitude vs. total pump power.](image2)
Dependence on $^{87}$Rb vapor density

**Low pumps power**

**High pumps power**

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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 $\approx 6$ mW

![Graph showing pulling factor against $D_2$ laser detuning from $F_g = 2 \rightarrow F_e = 3$, MHz]

Pumps power $\approx 180$ mW

![Graph showing pulling factor against $D_2$ laser detuning from $F_g = 2 \rightarrow F_e = 3$, MHz]

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Summary

- Improved puling factor: $0.005 \rightarrow 0.3$ with increased finesse $(20 \rightarrow 70)$
- Increased pump lasers power $(6 \text{ mW} \rightarrow 200 \text{ mW})$ pushed the pulling factor to 1
- Setup has widely tunable response influenced by
  - pump lasers power and detuning
  - density of $^{87}\text{Rb}$ atoms
  - cavity finesse
- This allows us to tune the response of the system on demand

We are grateful for financial support to

![NAV_AIR](image)