Fast gyro

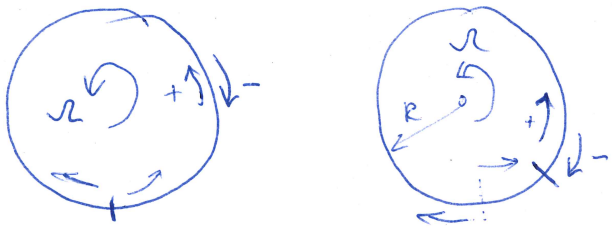
Eugeniy E. Mikhailov

The College of William & Mary, USA

SPIE 2014, Febrary 04, 2014

Sagnac effect

Gyro



$$\Delta L_{\pm} = \Omega \cdot R \cdot T = \Omega \cdot R \cdot \frac{2\pi R}{c} =$$

$$= 2 \cdot \underbrace{\pi R^2}_{A} \frac{\Omega}{c}$$

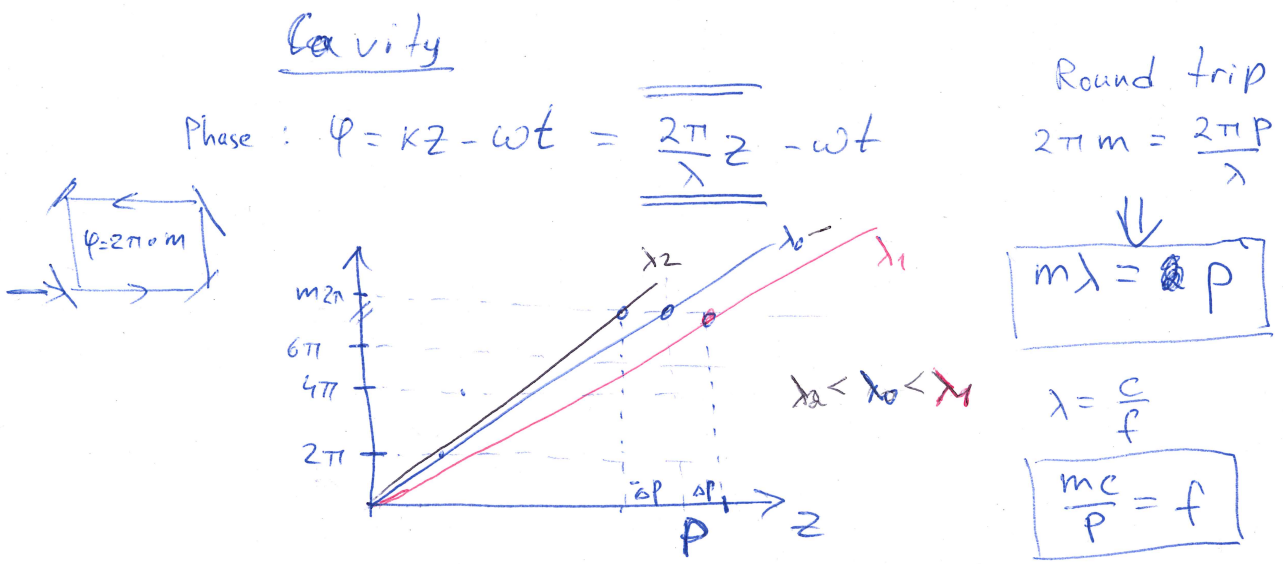
$$\boxed{\Delta L_{\pm} = 2 \frac{A \Omega}{c}}$$

Sagnyac effect

$$\Delta L \Rightarrow \Delta \varphi_{\pm} = 2\pi \frac{\Delta L_{\pm}}{c}$$

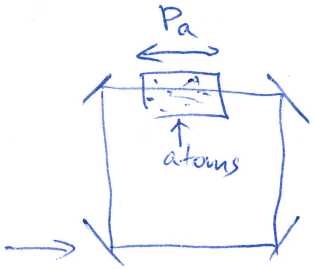
$$\boxed{\Delta \varphi_{\pm} = \frac{4\pi A \cdot \Omega}{c^2}}$$

Cavity conditions



if cavity length changes so must the resonant wavelength

Atoms in the cavity and Frequency shift derivation



$$m\lambda_0 = m\frac{c}{f_0} = p_a n(f_0) + p_{rest} = p_{optical}$$

$$\Rightarrow \quad m = \frac{f_0}{c}\left(p_a n(f_0) + p_{rest}\right)$$

$$m = \frac{f_\pm}{c}\left(p_a n(f_\pm) + p_{rest}\right) + \Delta L_\pm$$

$$m = \frac{f_0 + \Delta f_\pm}{c}\left[p_a\left(n f_0\right) + \frac{\partial n}{\partial f}\Delta f_\pm\right) + p_{rest} + \Delta L_\pm\right]$$

$$0 = \frac{\Delta f_\pm}{c}\left[p_a \frac{\partial n}{\partial f}\Delta f_\pm + p_{rest} + \Delta L_\pm\right]$$

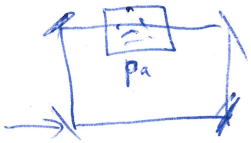
$$m \approx \underbrace{\frac{f_0}{c}\left[p_a\left(n(f_0)\right) + p_{rest}\right]}_{m} +$$

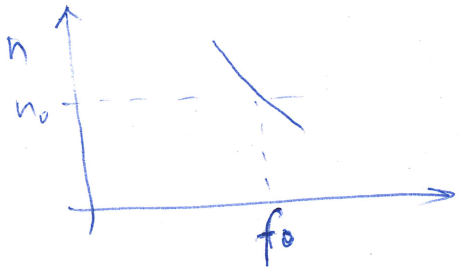
$$+ \frac{f_0}{c}\left(\frac{\partial n}{\partial f}\Delta f_\pm p_a + \Delta L_\pm\right) +$$

$$+ \frac{\Delta f_\pm}{c}\left[p_a n(f_0) + p_{rest} + \Delta L_\pm\right)$$

$$\frac{\Delta f_\pm}{c}\left(n_0 + f_0\frac{\partial n}{\partial f}\right)p_a = -\frac{f_0}{c}\Delta L_\pm$$

Negative dispersion sensitivity enhancement





$$\Delta f_{\pm} \simeq \frac{-f_0 \Delta L_{\pm}}{P_a\left(n_0 + f_0 \frac{\partial n}{\partial f}\right) + P_{rest}}$$

$$P_{rest} \ll P_a \Rightarrow \boxed{\Delta f_{\pm} \simeq \frac{-f_0 \Delta L_{\pm}}{P_a\left(n_0 + f_0 \frac{\partial n}{\partial f}\right)}}$$

$-\frac{\partial n}{\partial f} \Longleftrightarrow$ "fast" Light

Note that

Group velocity

$$v_g = \frac{c}{n_0 + f_0 \frac{\partial n}{\partial f}}$$

$$\boxed{v_g < 0 \Longleftrightarrow \frac{\partial n}{\partial f} < 0}$$

Sensitivity estimate

Some estimates

$\Delta f = 1\,\text{kHz}$

$f_0 (\lambda = 795\,\text{nm}) = 3.77 \cdot 10^{14}\,\text{Hz}$

$P = 0.8\,\text{m}$

$n_0 = 1\,, \quad \frac{\partial n}{\partial f} = 0$

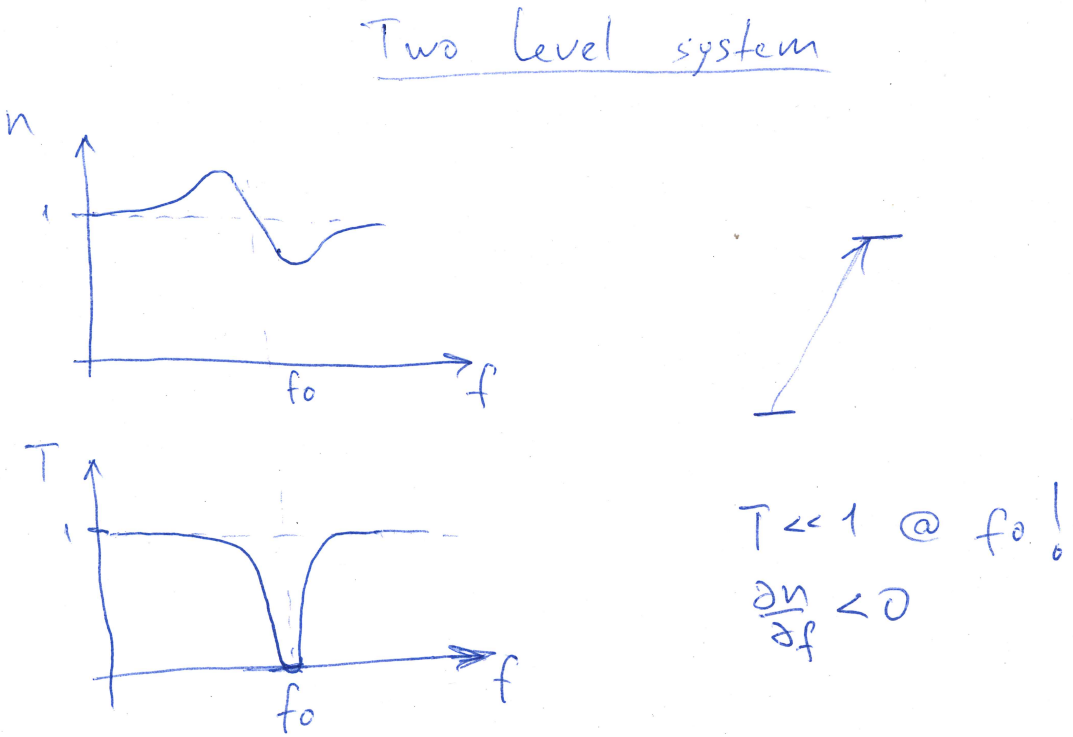
$A = 0.2^2 = 4 \cdot 10^{-2}\,\text{m}$

$$\Omega = \frac{\Delta f \cdot P}{f_0} \frac{c}{2A} = \frac{1 \cdot 10^3 \cdot 0.8}{3.77 \cdot 10^{14}} \cdot \frac{3 \cdot 10^8}{8 \cdot 10^{-2}}$$

$\approx 8 \cdot 10^{-3}\,\text{1/s} \approx 10^{-3}\,\text{Hz}$

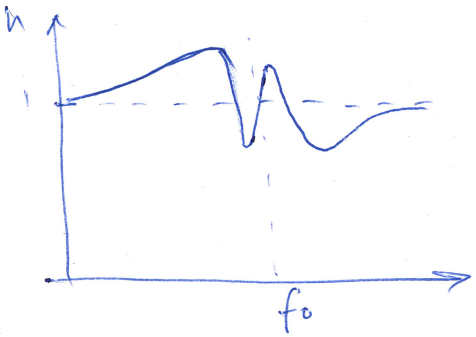
$1\,\text{rev}/1\,\text{day} \Rightarrow \Omega = 1.5 \cdot 10^{-5}\,\text{Hz}$

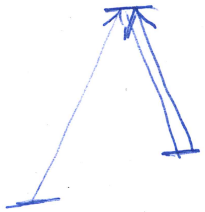
Two level atom dispersion

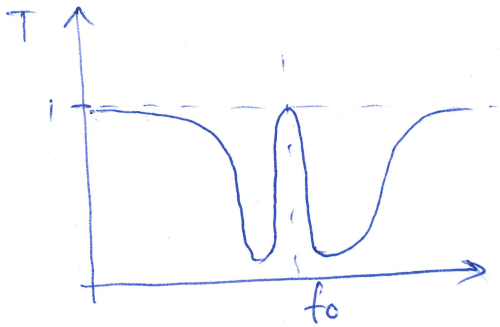


3 coupled levels: EIT

3 level coupled system: EIT



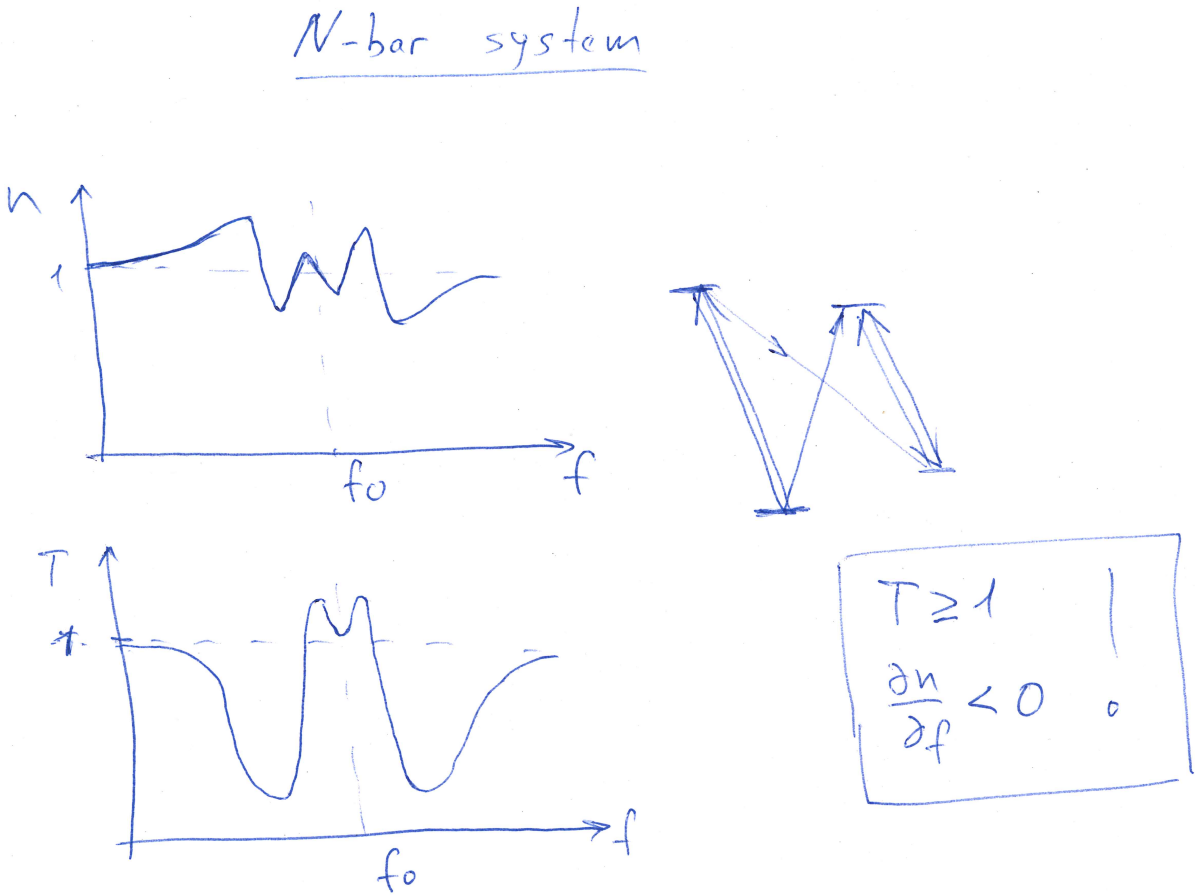




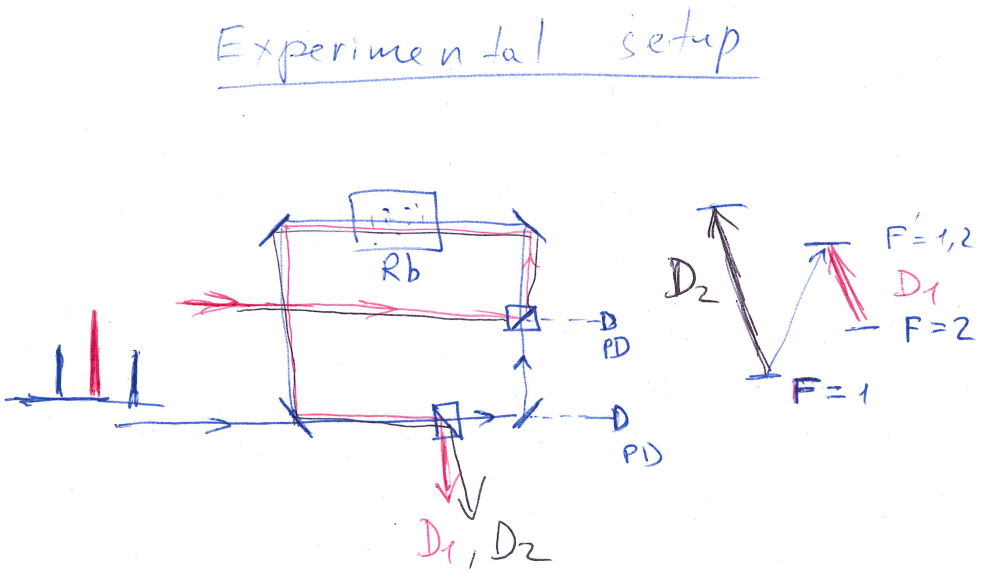
$T \leq 1$ @ f_0

but $\frac{\partial n}{\partial \omega} > 0$

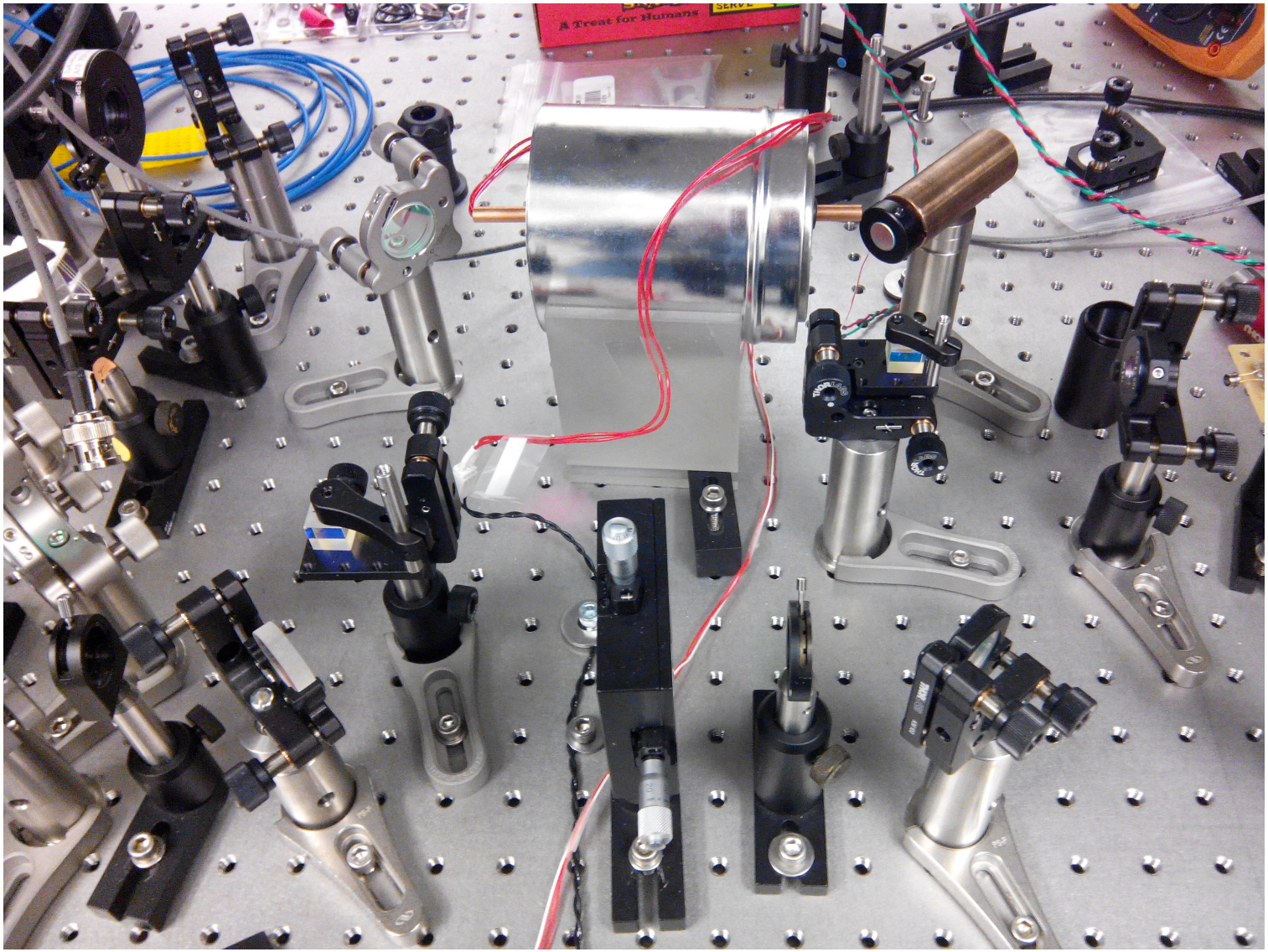
N-bar scheme



Schematic experimental setup



Experimental setup



Goals

Short term, almost certain to work

- demonstrate EIT in the cavity (almost done)
  - lock to the probe laser, sweep two-photon detuning
- show that we can obtain gain with additional pump laser
- cavity + gain = laser: see the lasing if we have enough power
- play with gain to adjust dispersion, observe cavity line narrowing

Long term, less likely to *just* work

- see amplification and lasing of counter propagating beam, without seeding
  - fall back scenario: seeding the counter propagation or counter propagating pump/control

Electronics/laser locks

- lock cavity to yet another frequency related to the probe to avoid lock drop if we lose gain/transmission
- pump laser frequency lock
- power stabilizers

Spin the gyro