High-sensitivity atomic magnetometer for neutron EDM Experiment

Moushumi Das

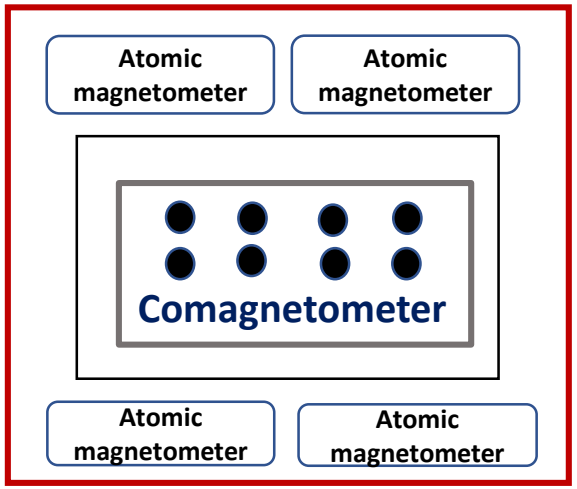
TUCAN Collaboration Meeting

August, 08 2018

Goals:

- Precision $\delta d_n = 10^{-25}$ e-cm / 100 s.
- Measurement of field at 16 fT over 100 s
- Field stability at 1-10 pT over 100 s.

- **Requires to make use of highly sensitive magnetometers**



Concept:
Place a number of atomic magnetometers around the nEDM cell to deduce the field and its vertical gradient.

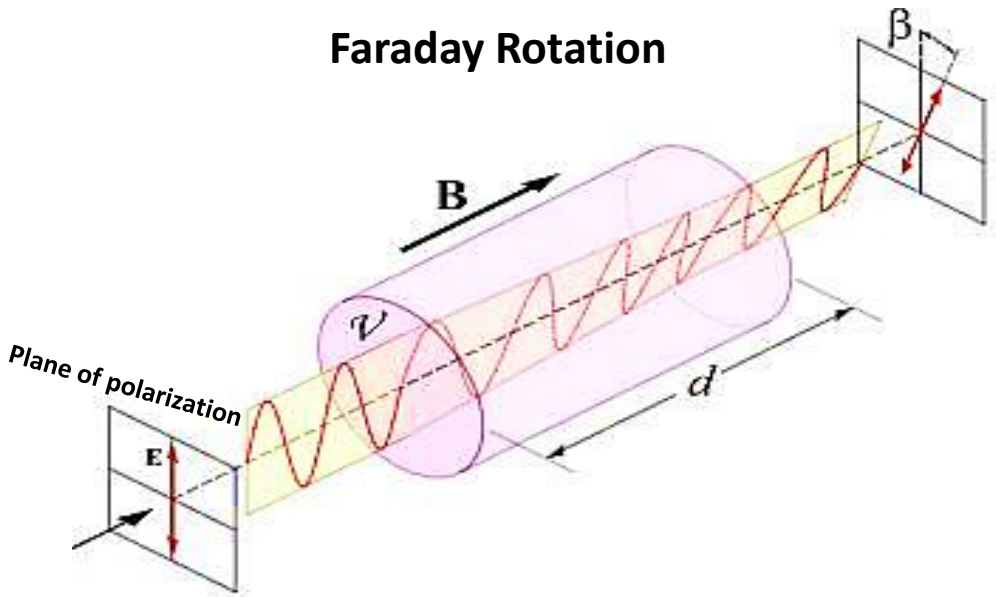
My work:
Investigate the sensitivity and stability of a highly sensitive nonlinear magneto-optical rotation (NMOR) based Rb magnetometer.

Nonlinear Magneto-optical Rotation(NMOR)

- Faraday rotation is a linear effect because rotation is independent of light intensity.

- When linearly polarized light interacts with an atomic transition in the presence of a magnetic field, the polarization angle of the light can be rotated. When the rotation angle depends on the light intensity, the effect is called nonlinear magneto-optical rotation (NMOR).

- NMOR magnetometry depends on the induced birefringence of alkali vapour in a magnetic field

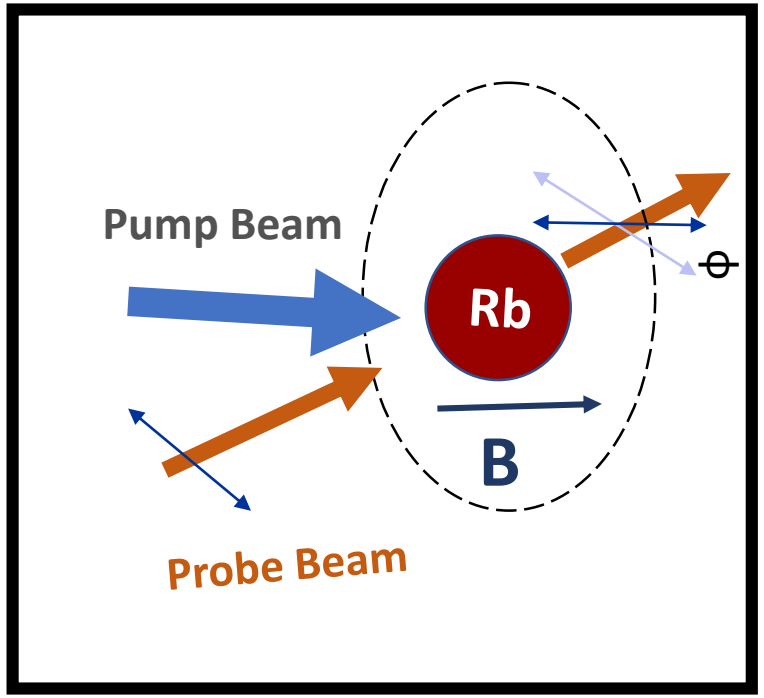


https://en.wikipedia.org/wiki/Faraday_effect

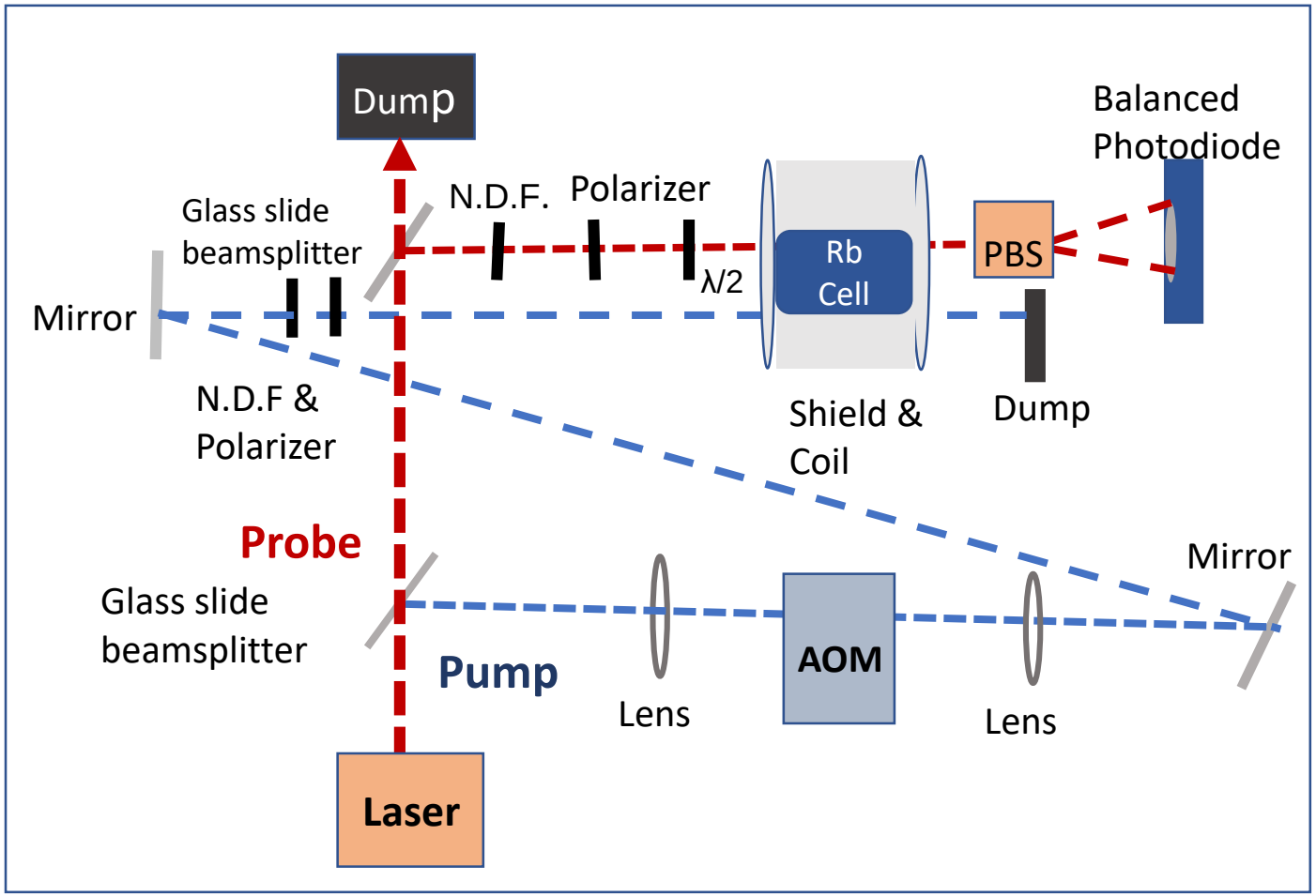
NMOR based Rb magnetometer

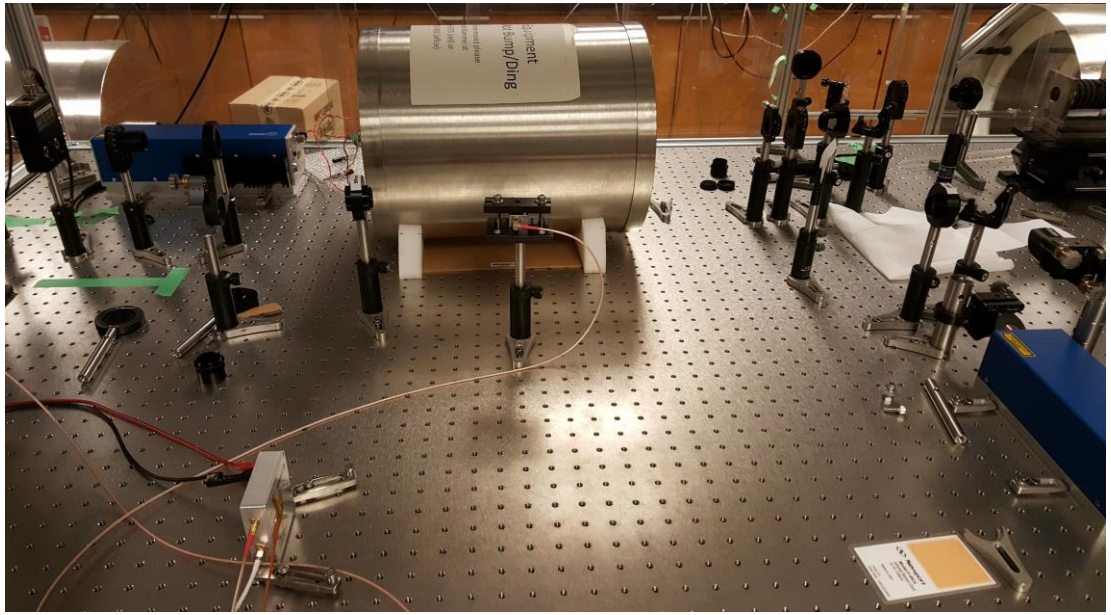
How does it work ?

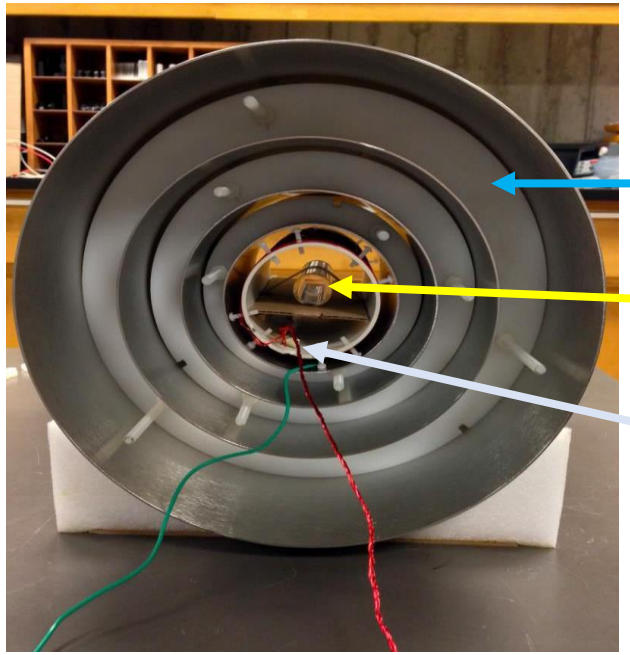
- Resonant light polarizes Rb atoms via optical pumping. Magnetic moments of the atoms are oriented with respect to the axis of alignment.
- Aligned magnetic dipole moments experience a torque and precess around the axis of the field at the Larmor frequency and medium becomes birefringent
- Optical polarization rotation of a probe beam is used to measure magnetic field



Apparatus







Signal processing system

Different operational modes of an atomic magnetometer

- Continuous oscillation mode
  - AM NMOR (amplitude modulated nonlinear magneto optical rotation).
  - FM NMOR with amplitude modulated light.
- Free Induction Decay(FID).

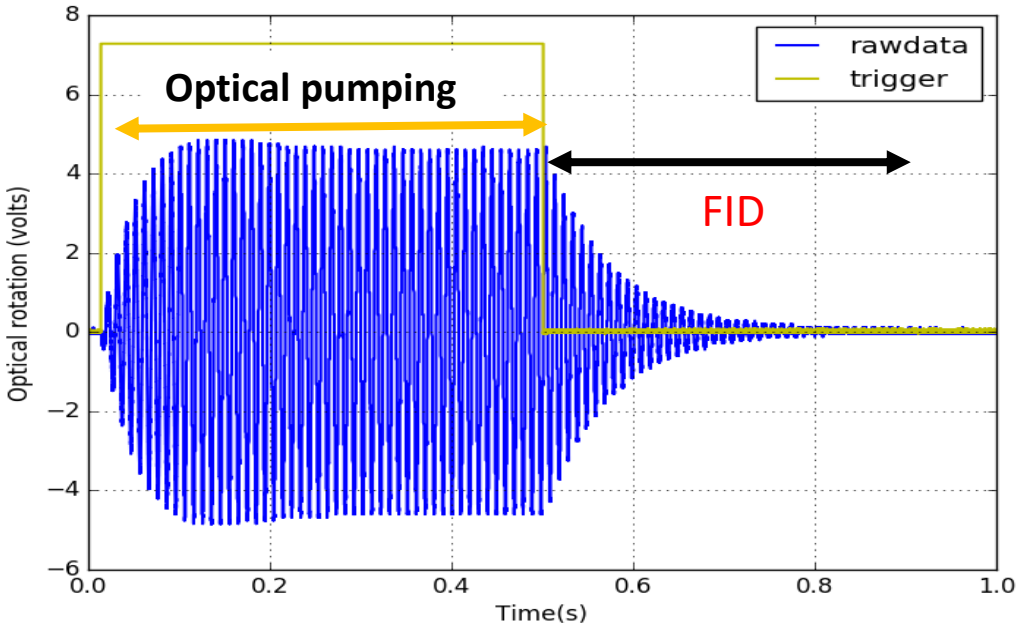
Free induction decay (FID)

Experimental procedure:

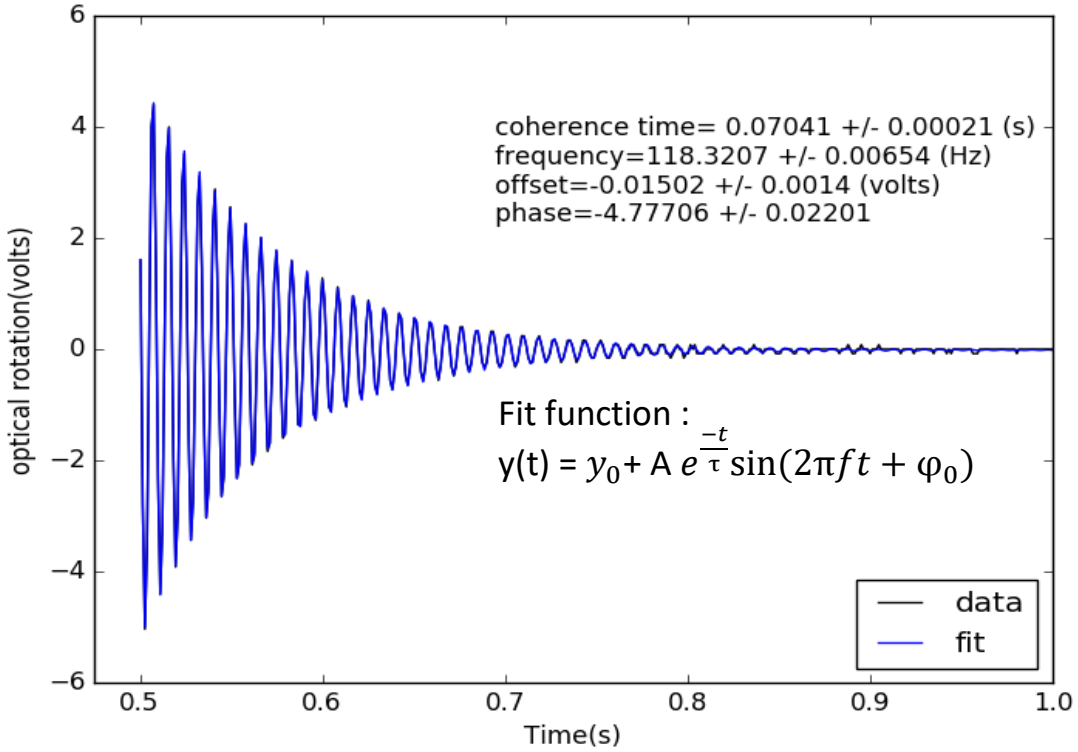
1. Rb atoms inside the cell is excited once and afterwards the decaying processes of the excited atoms is observed. A function generator is used to delivered the pump pulses which are necessary for pumping during a FID measurement.

2. Pumping is done for a very short time interval and the coherence decay takes place fast.

3. The reference signal on the lock-in amplifier has further to be set slightly off resonance (~ 100 Hz) in internal frequency mode in order to properly record the FID.



Single FID measurement



How do I calculate the magnetic field and uncertainty in magnetic field?

$$Magnetic\ field, B = \frac{frequency}{2\gamma}$$

For Rubidium
$\gamma = 4667\ Hz/\mu T$

Rb Magnetometer sensitivity

- Allan Deviation, $\sigma_{ADEV} = \sqrt{\frac{1}{2} < (y_{n+1} - y_n)^2 >}$

  Where $y_n \longrightarrow$ nth average over τ.

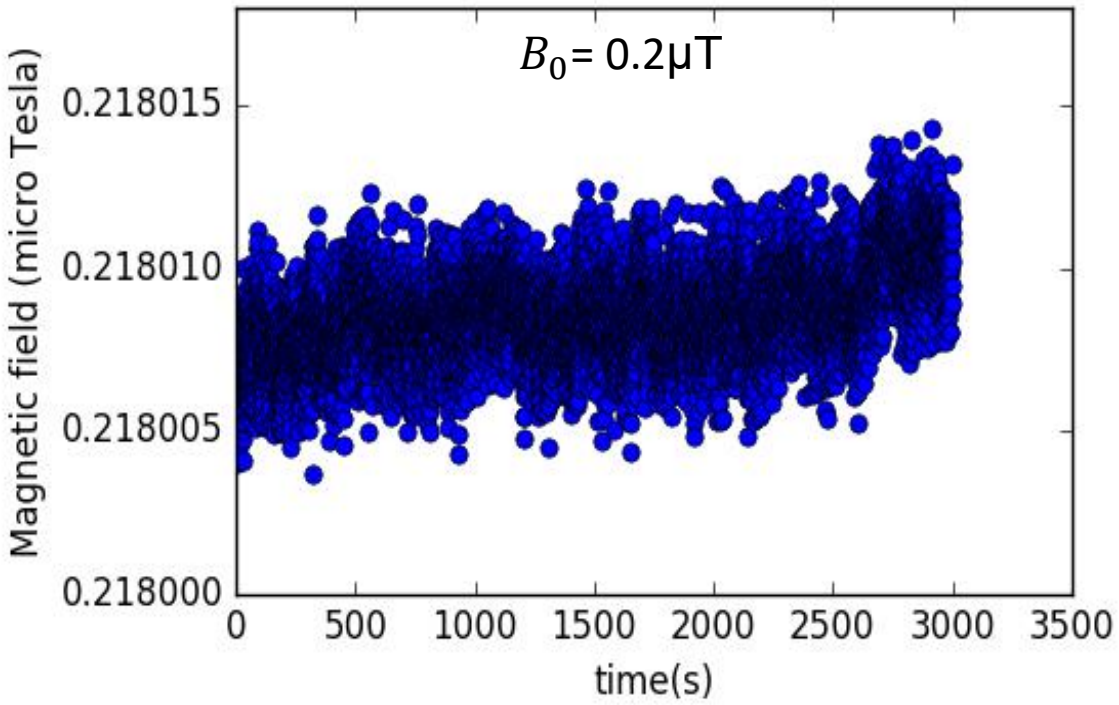
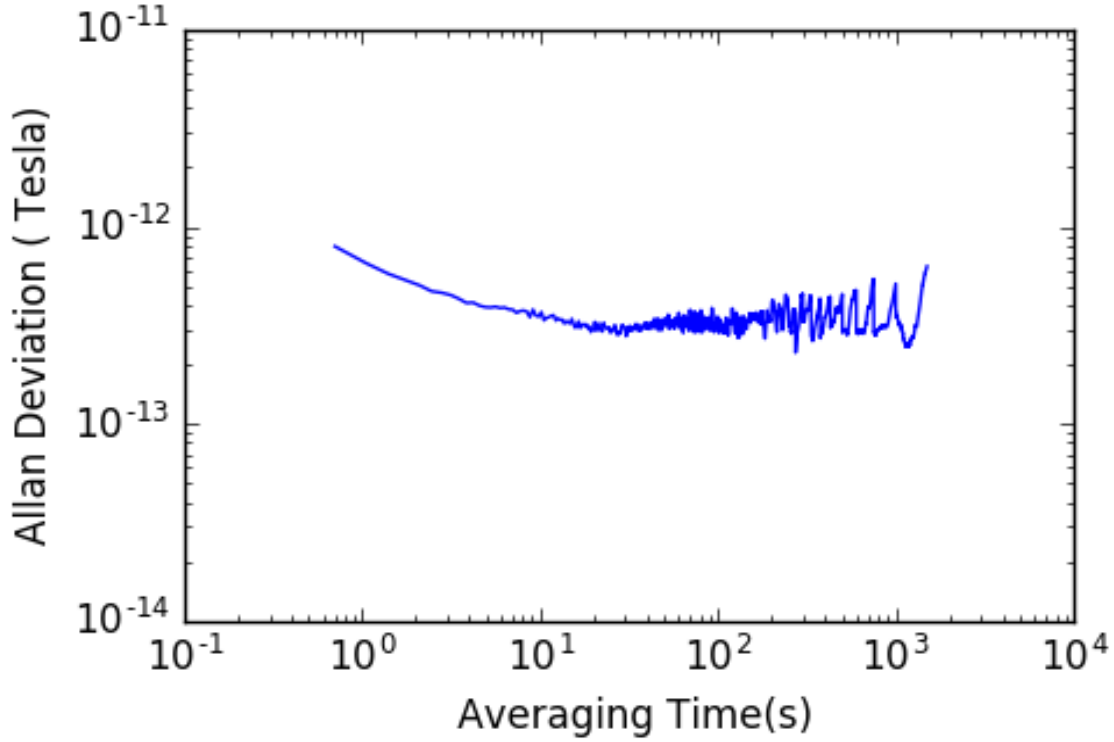


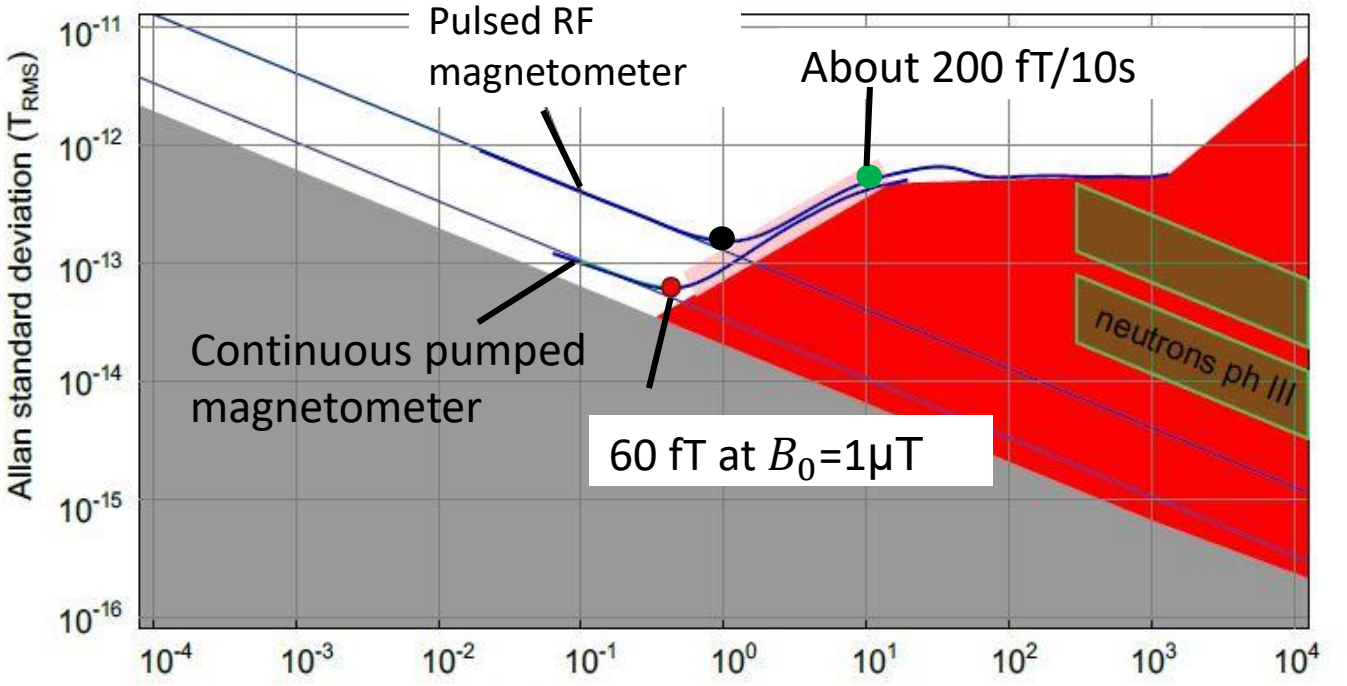
Figure: Long-term FID measurement



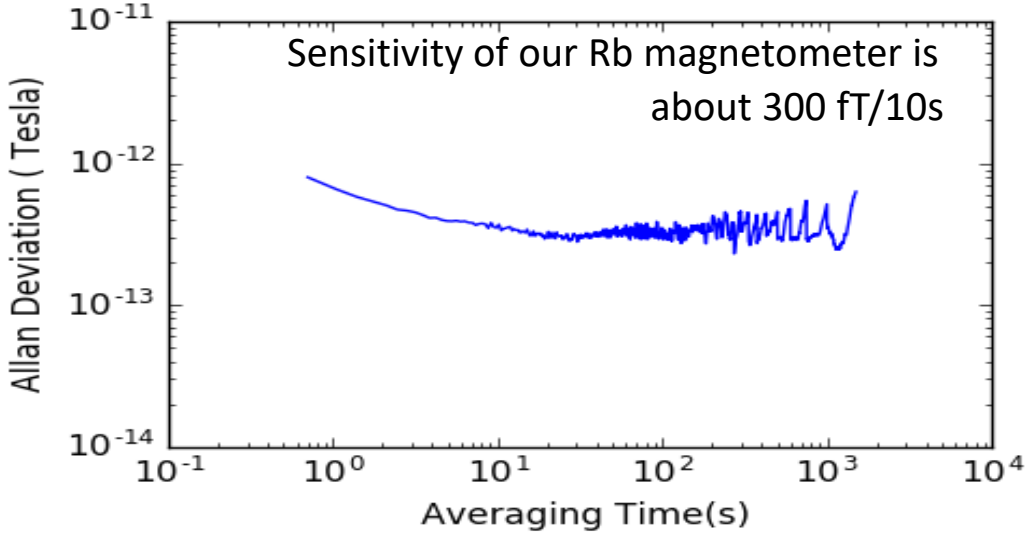
Current Status:

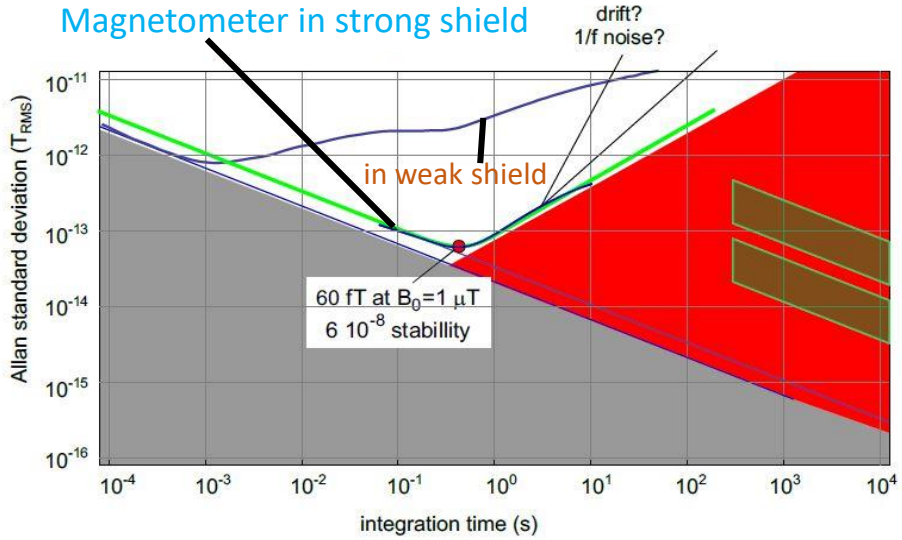
- Measurement of field is about 300 fT over 100 s

Result Comparison with Cs magnetometer



Graph from Georg Bison (PSI group)





Graph from Georg Bison (PSI group)

Things need to do for better magnetometer sensitivity

- Maximization of signal amplitude
  - Adjusting probe/ pump power
- Recheck optics alignment
- Improve our existing shield degaussing system

Thank You