CsM Based Monitoring of a Current Source

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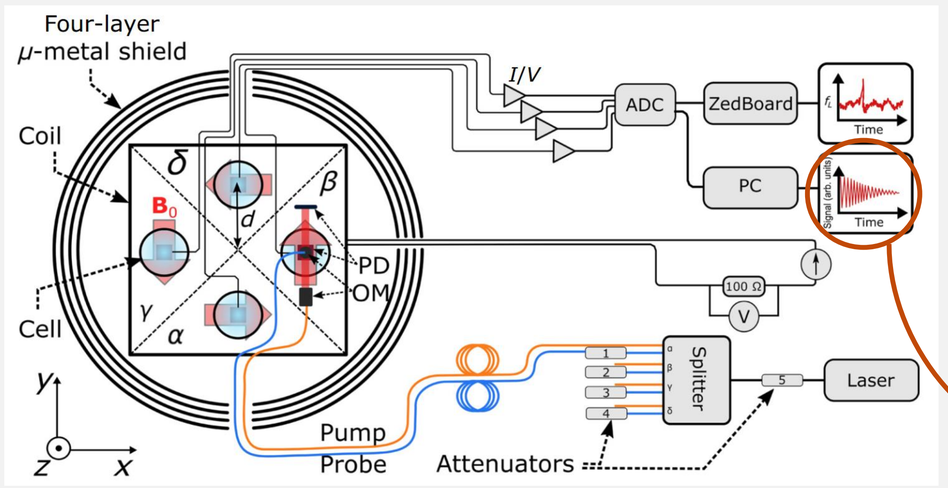
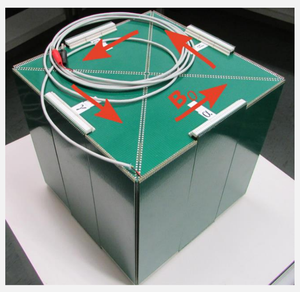
Abstract: The high sensitivity and accuracy of Cs magnetometers (CsM) is exploited for the development of a current source monitoring system. By placing a series of magnetometers in a specific configuration (in pairs) inside a field-confining coil, the influence of the first order gradient of the external magnetic field is reduced. If a feedback loop is implemented, the current source can reach a stability of 4×10^{-9} for a time interval of around 70 min. The monitoring feature of the developed system can be utilized in the n2EDM measurement to monitor the current source that is used to generate the B_0 field. The team at KULeuven is also involved in the development of the DAQ system used for the Cs gradiometer of the n2EDM project.

Principle

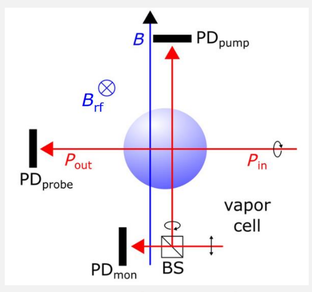


- 4 magnetometers in a cubic field-confining coil → polarization of optically pumped Cs vapour precesses around generated magnetic field
- $i(t) = \frac{\sum_{j=\alpha,\beta,\gamma,\delta} B_j + 2d(B'_x - B'_y)}{\sum_{j=\alpha,\beta,\gamma,\delta} \lambda_j}$

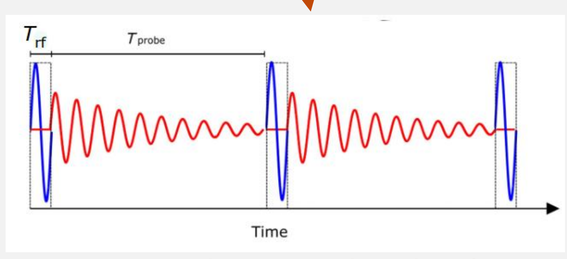
$$\boldsymbol{B}_j(x,y,t) = \boldsymbol{B}_{coil,j}(x,y,t) + \boldsymbol{B}_{ext,j}(x,y,t)$$



Pictures of field-confining coil with α, β, γ and δ compartments

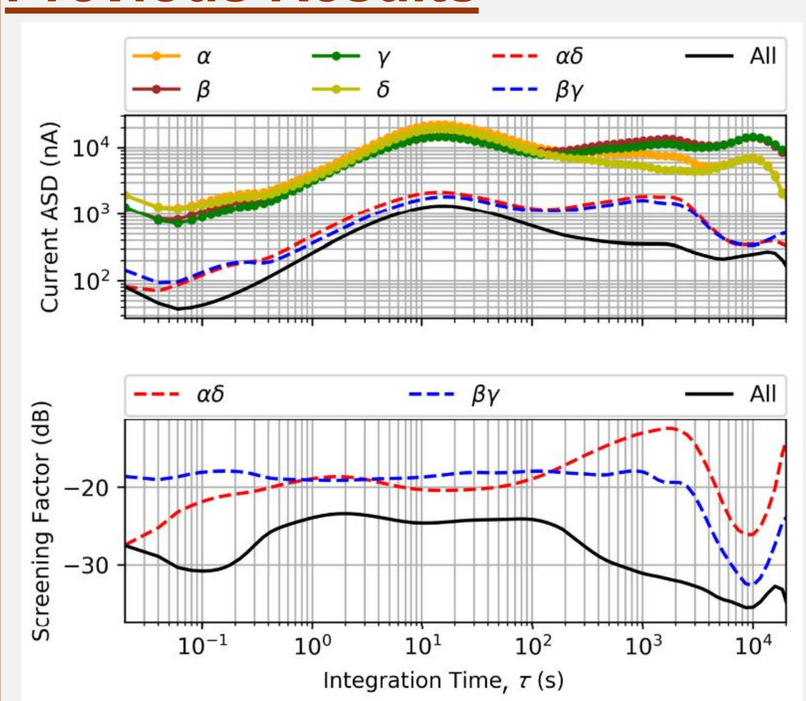


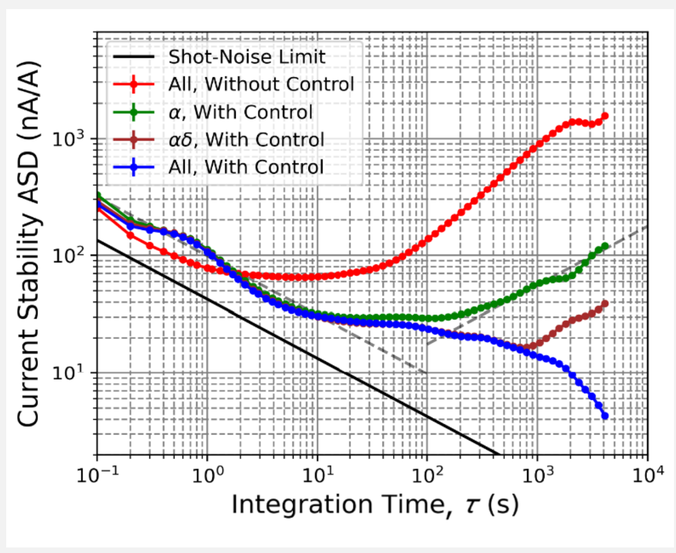
Pumping and Probing of a Cs vapour cell



Free Spin Precession signal (decaying sine wave)

Previous Results





(LEFT) The current Allan Standard Deviation for the separate magnetometers, the pairs and all of them together. Also, the screening factor introduced by using this configuration. (RIGHT) The current stability ASD for this configuration with feedback control to the current source (blue line).

How effective is the external magnetic field canceled by the system?

- Screening factor for combination of four CsM outperforms the screening factor for the pairs
- Screening factor depends on uniformity of external magnetic field $\boldsymbol{B}_{ext}$ and coil design
- Expected that the stability of the system improves because of the screening effect

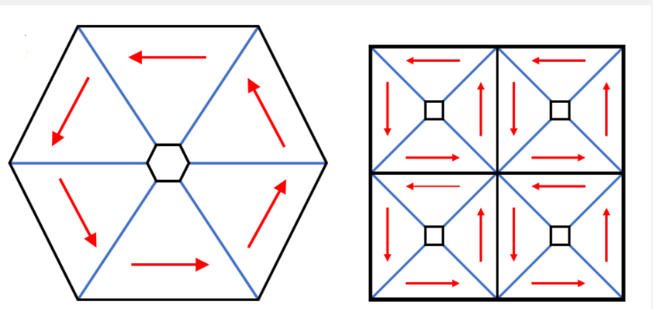
What current source stability can be reached with feedback control?

- On larger timescales, feedback controlled system outperforms ASD of system without control
- $20\ mA\ current\ (10\ \mu T)$: best stability of 4×10^{-9} for 70 min of averaging

Outlook

Increasing the number of pairs and improving the geometry of the coil, improves the **screening factor** → Influence of higher order gradients of external magnetic field is reduced

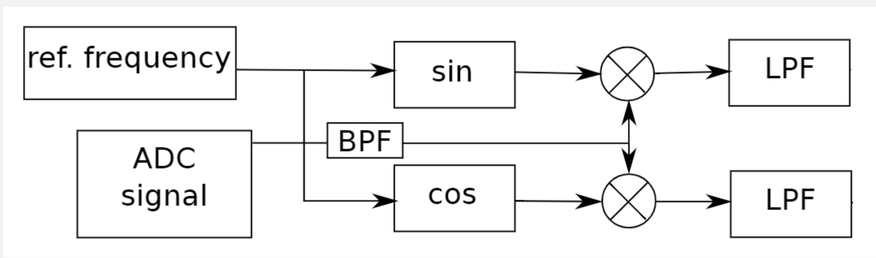
Study the dependencies between the **sensitivity and stability** of the set-up and environmental factors such as temperature, time of day etc.



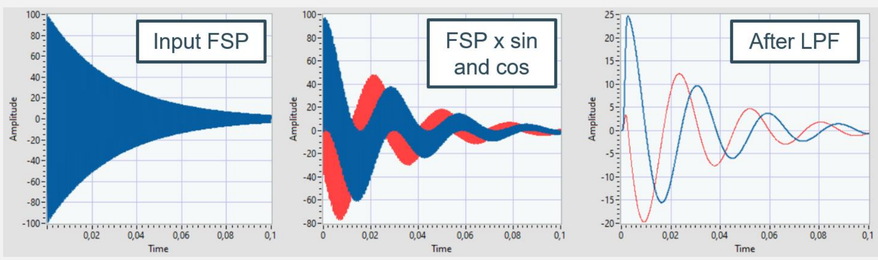
CsM DAQ

n2EDM @ PSI:
CsM gradiometer: 100+ magnetometers (being developed at PSI)

- Fitting of every Free Spin Precession signal is time consuming and not efficient (especially for 100+ CsM) → demodulation and downsampling (LPF)



- ADC signal is multiplied with sine and cosine wave with a reference frequency → sum and difference of the frequencies

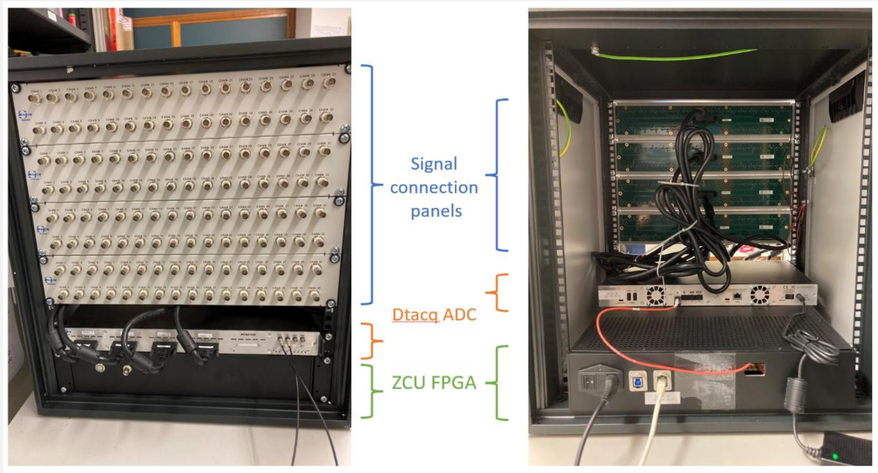


multi-channel ADC (D-tAcq)

→ 128 channels × 24 bit vertical resolution × 50 kHz sampling rate ≈ **20 MB/s**

FPGA pre-processing system for demodulation and lower bandwidth stream

→ 128 channels × (32 bit sine + 32 bit cosine) × 1kHz sampling rate ≈ **1 MB/s**



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