

Atomic-optical compass with pT precision

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Magnetic fields and magnetometers capabilities



Magnetic field

- Human brain:
0.1 – 1 pT
- Human heart:
100 pT

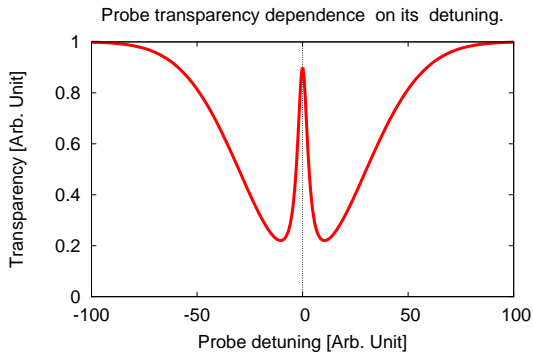
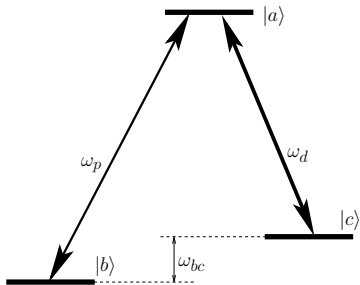
Magnetometers

- SQUID: 1 fT
- SERF: 1 fT

Goal

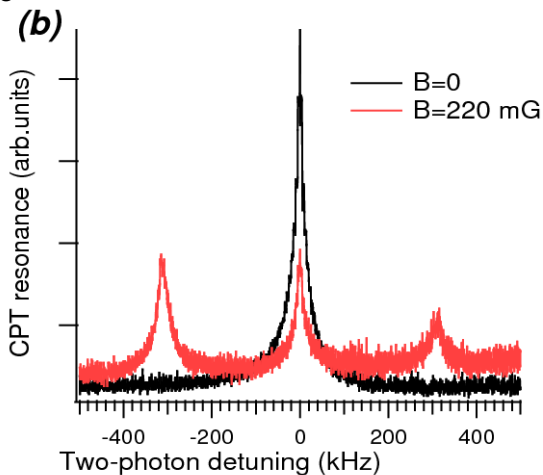
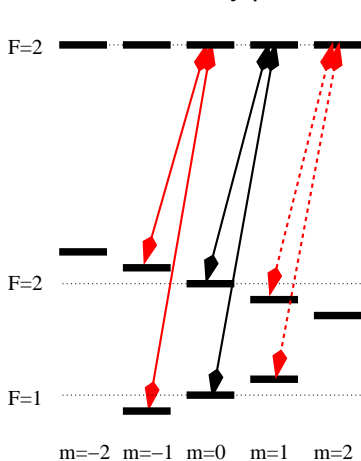
We are looking for compact (less 1 cm³) **vector** magnetometer with pT precision capable to work at Earth magnetic field (50 μ T)

Electromagnetically Induced Transparency (EIT)

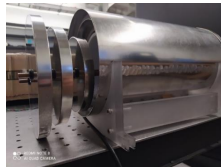
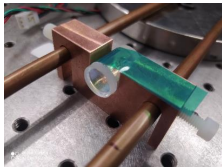
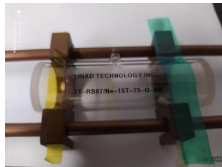
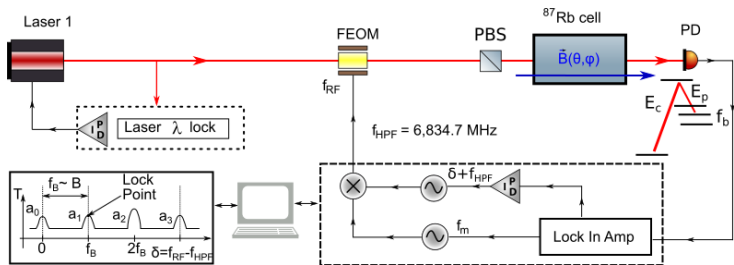


Simple EIT magnetometer

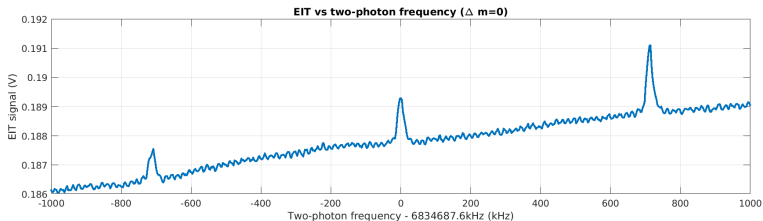
EIT with circularly polarized light



Conceptual design



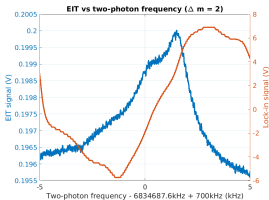
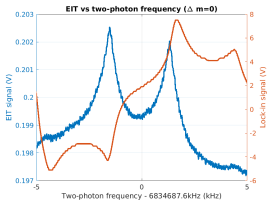
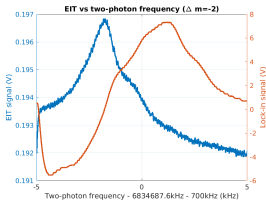
EIT signals vs two-photon detuning. $B=50\mu\text{T}$, $f_{center} = 6'834'687.6\text{kHz}$



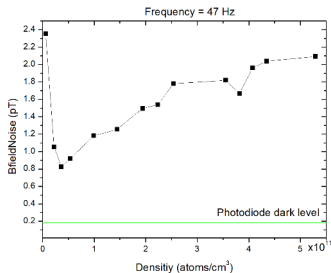
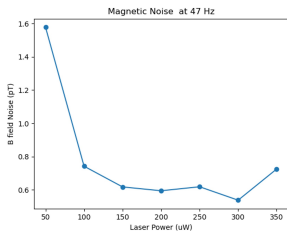
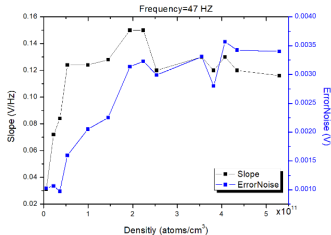
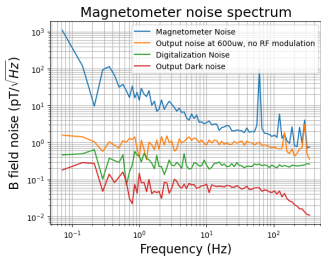
$\Delta m = -2$,
 $f_{center} - 700\text{kHz}$

$\Delta m = 0$,
 f_{center}

$\Delta m = 2$,
 $f_{center} + 700\text{kHz}$



Signal to noise optimization

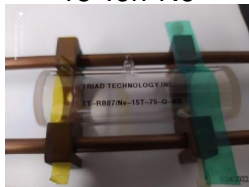


Optimization for different cells

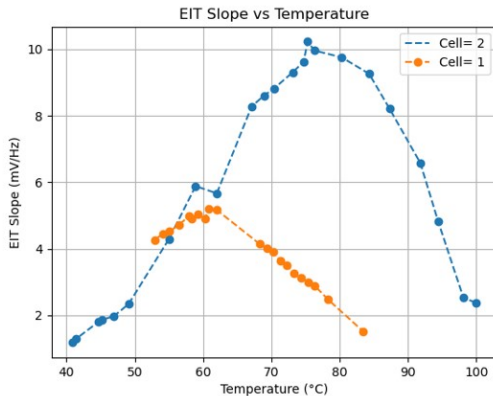
10 Torr Ne



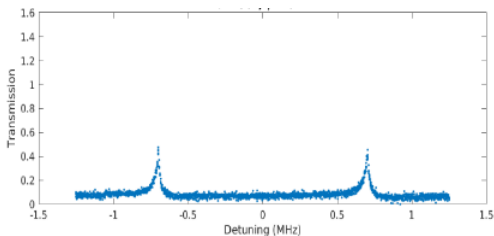
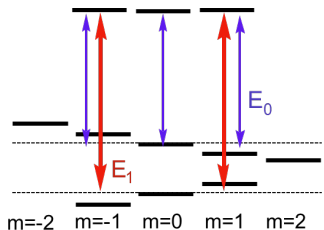
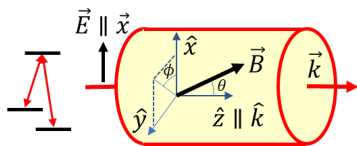
15 Torr Ne



Shorter cell with less buffer is better



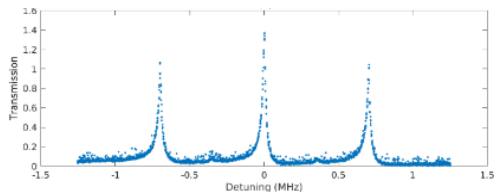
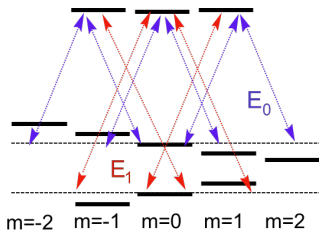
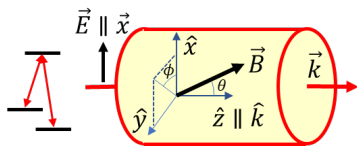
Compass idea



V. I. Yudin *et al.* Phys. Rev. A 82, 033807

Kevin Cox *et al.* Phys. Rev. A 83, 015801

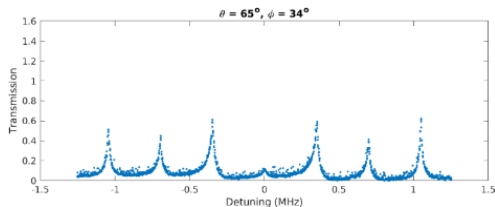
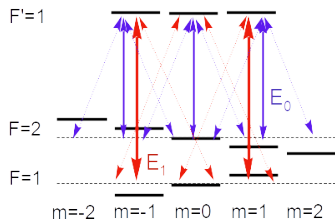
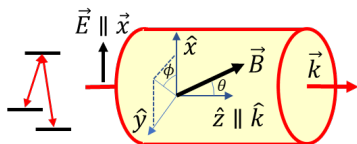
Compass idea



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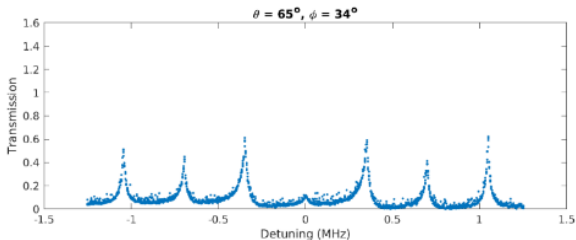
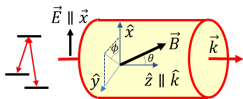
Compass idea



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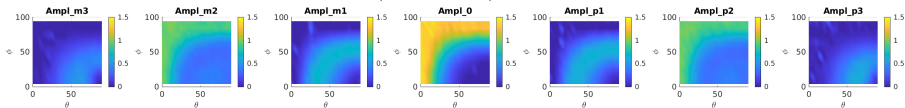
Kevin Cox *et al.* Phys. Rev. A 83, 015801

Linear polarization: angular dependence on θ and ϕ



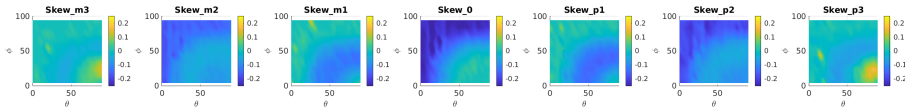
Amplitude

EIT parameter for linear polarization

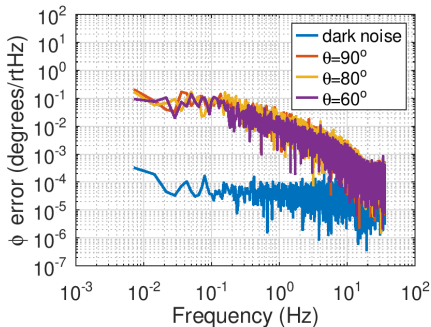
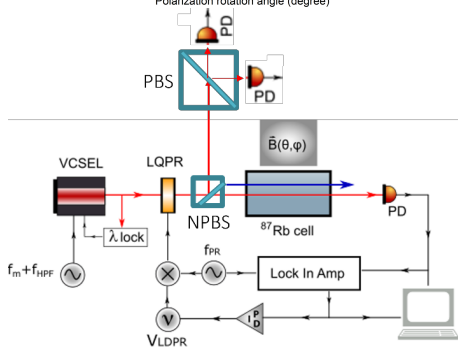
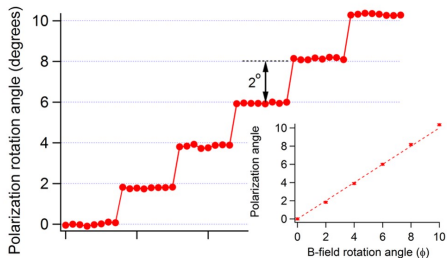
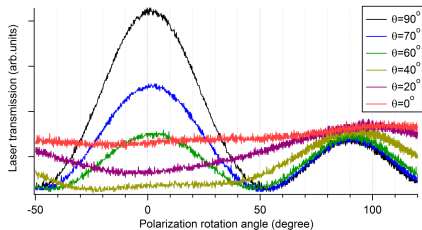


Skew

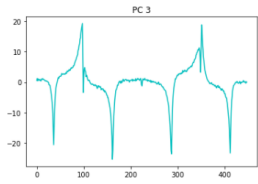
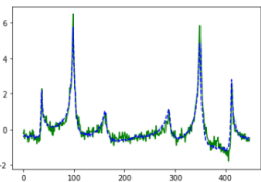
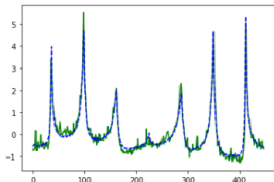
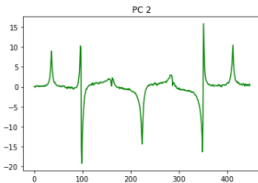
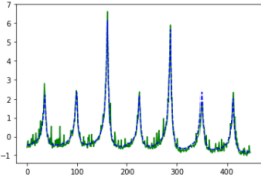
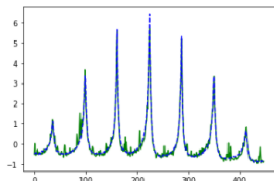
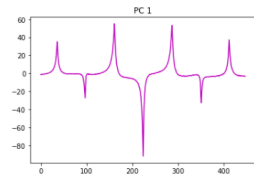
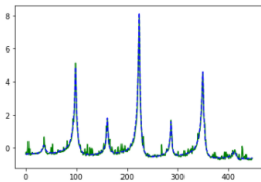
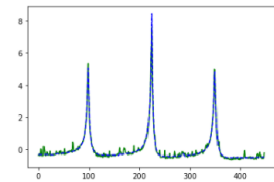
EIT parameter for linear polarization



ϕ angle tracking sensitivity

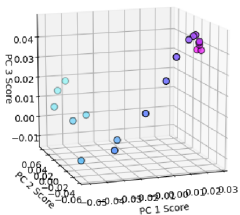


Principal component analysis: get components

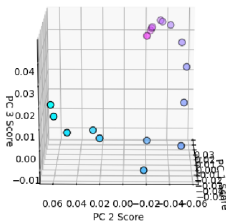


Principal component analysis: use components space

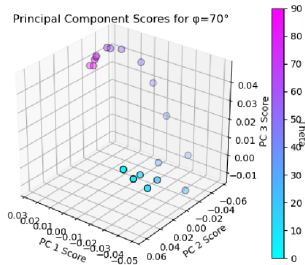
Principal Component Scores for $\varphi=70^\circ$



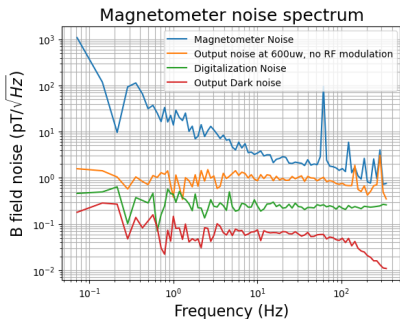
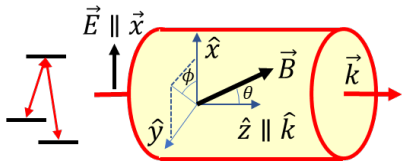
Principal Component Scores for $\varphi=70^\circ$



Principal Component Scores for $\varphi=70^\circ$



Compass summary



- pT sensitivity
- measures B-field vector
- operates at the Earth magnetic field