Femto-Tesla magnetometry with FID signals in Cs vapor

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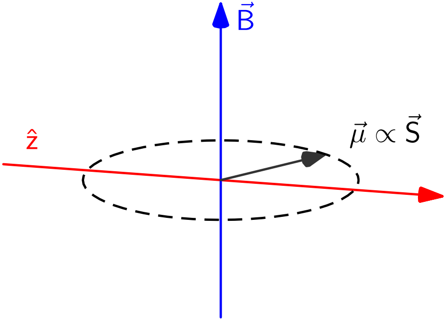
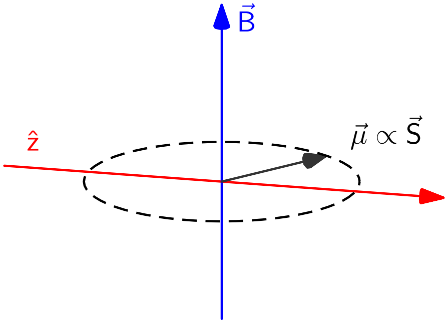
Atomic Physics


$\vec{B}$
$\hat{z}$
$\vec{\mu} \propto \vec{S}$



The magnetic moment $\vec{\mu}$ associated with the spin polarization $\vec{S}$ precesses at the Larmor frequency

$$\omega_L = \gamma_F |\vec{B}| \qquad \text{where} \qquad \frac{\gamma_F}{2\pi} \approx 3.5 \frac{Hz}{nT}$$

FID

=

Free Induction Decay

FID

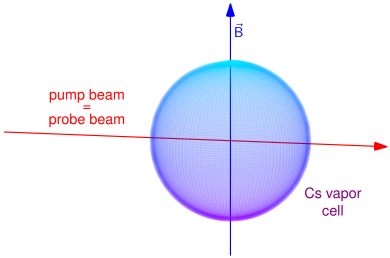
=

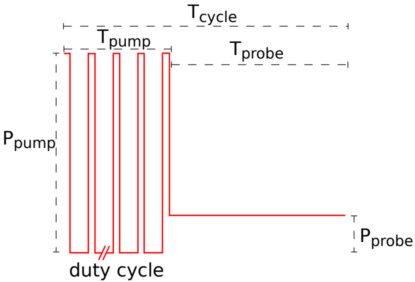
Free Induction Decay

=

Free Polarization Decay

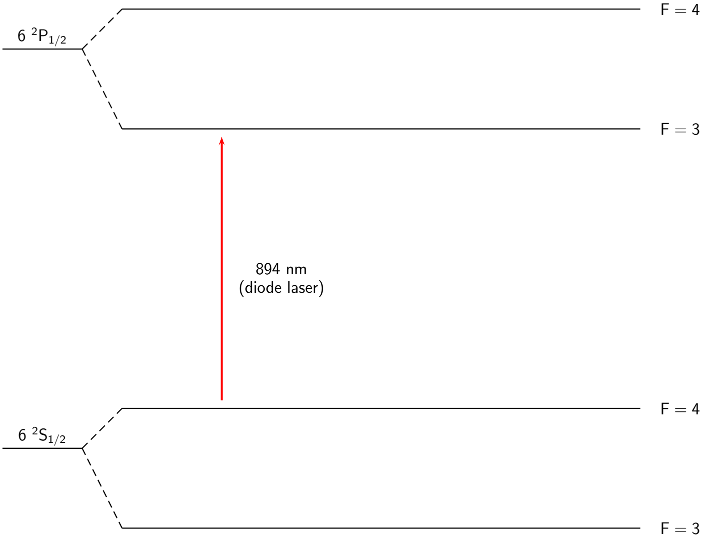
FID cycle





We use an amplitude modulated waveform with $\omega_{mod} = \omega_L$.

Optical pumping



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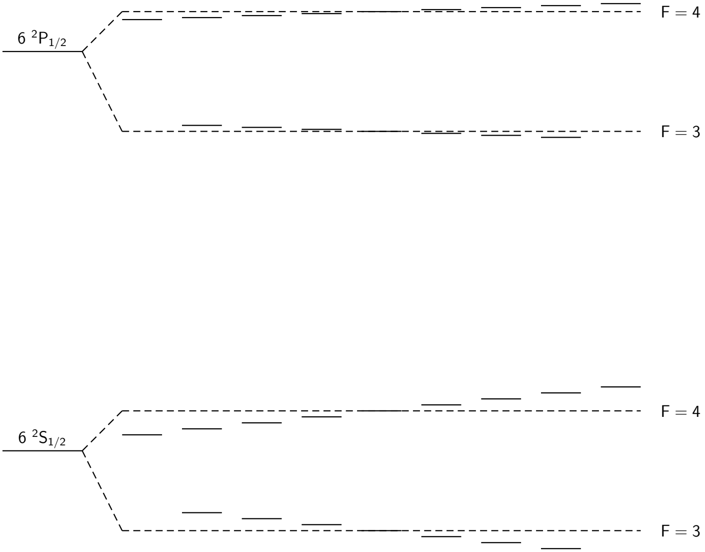

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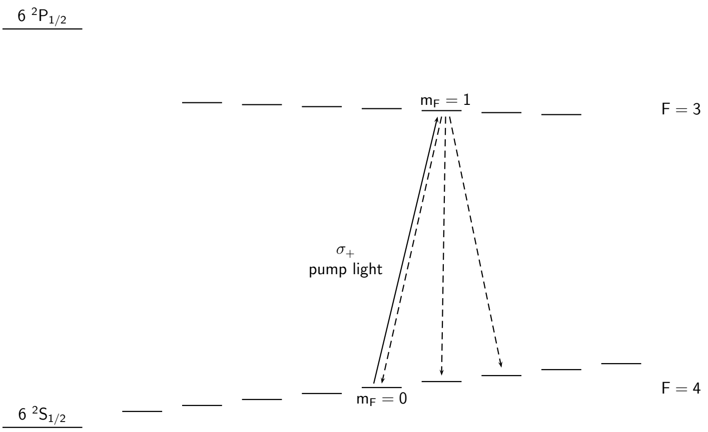

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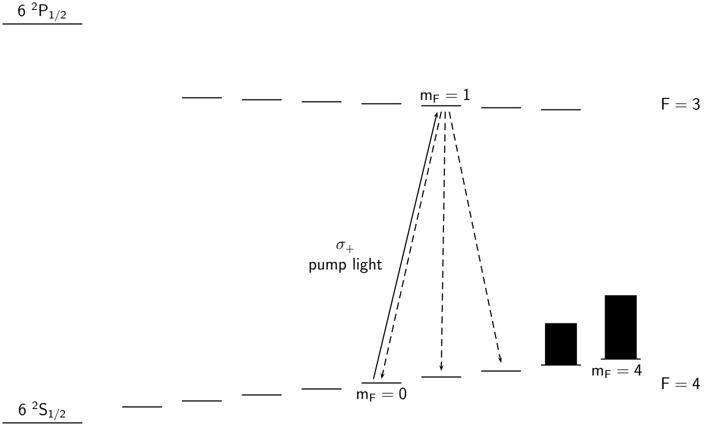
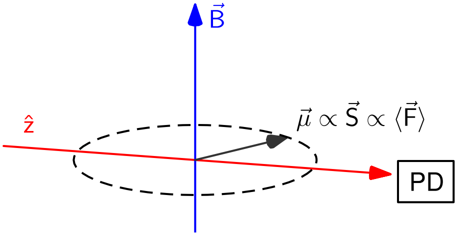


Basic idea



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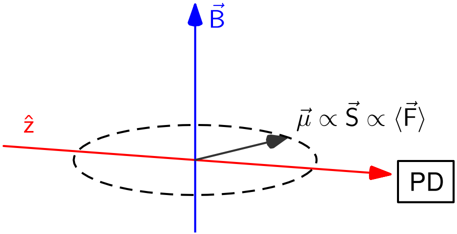

We can make a connection with the population distribution by using

$$\mu_z \propto \langle F_z \rangle \propto \sum_{m=-4}^{4} m \; p_m \; .$$

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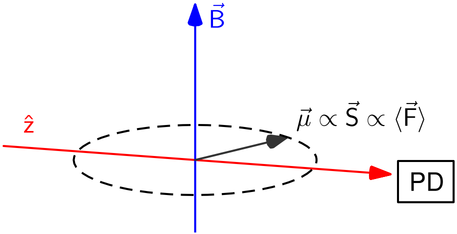

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The absorption coefficient can be written as

$$\kappa(t) = \kappa_0(1 - \vec{\mu} \cdot \hat{k}) = \kappa_0[1 - S_z(t)] = \kappa_0(1 - |\vec{S}| \cos \omega_L t) \; .$$

A free induction decay signal

By manually introducing a damping we get

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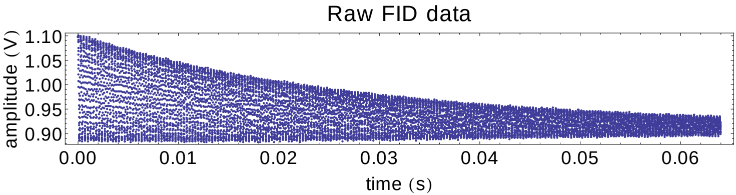

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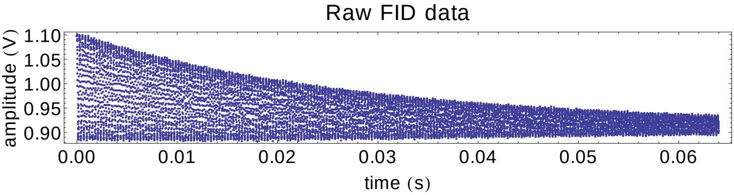

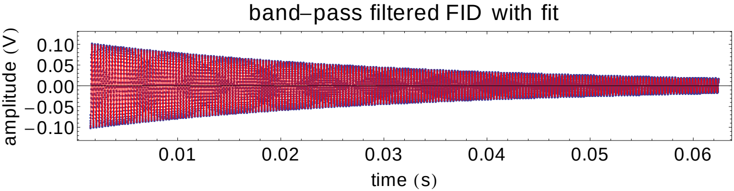

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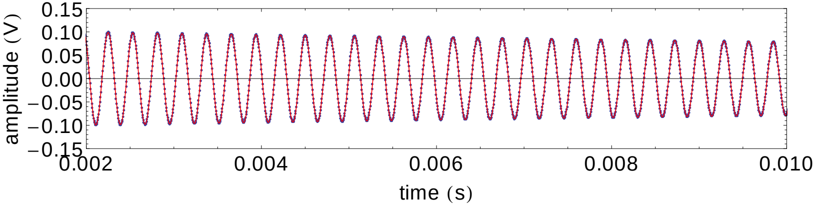

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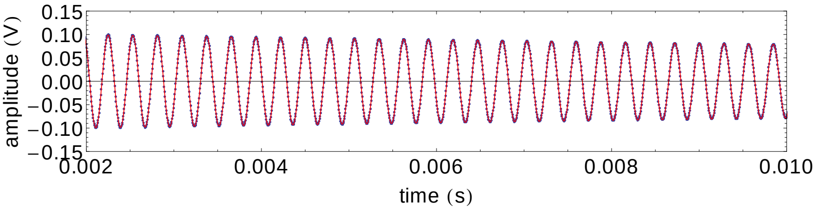

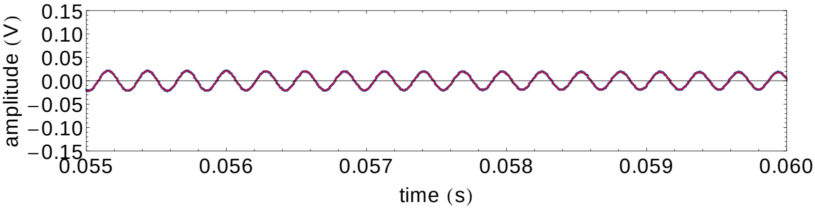

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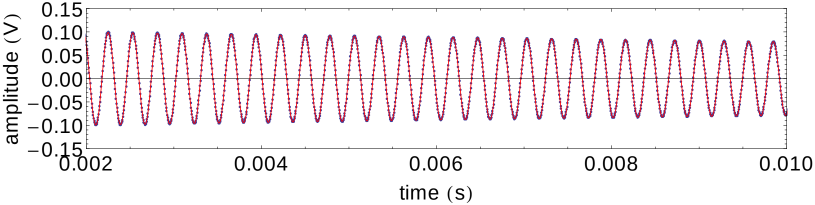

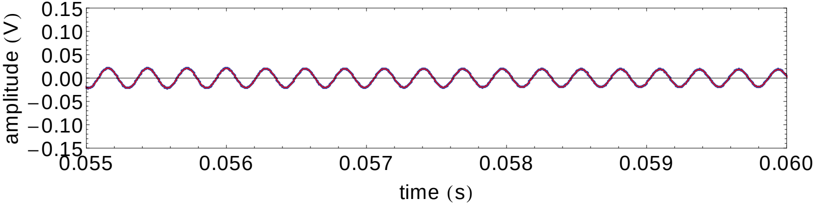

The fit of the FID yields

$$B = 1.0152622(2)\ \mu T\ .$$

Sensitivity characterisation

The magnetometric sensitivity of a single FID on the measurement time T_{probe} scales as

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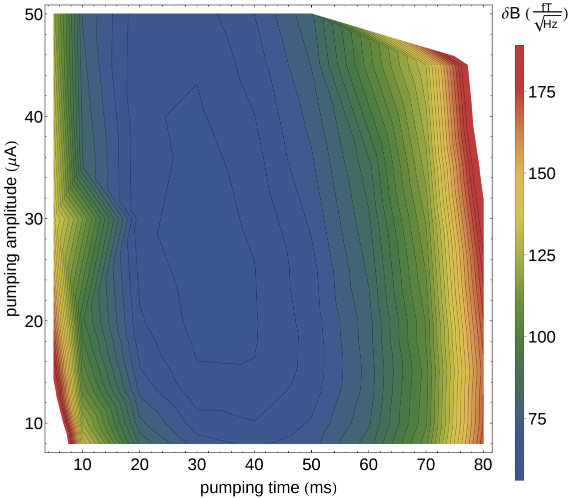
We typically get values of

$$\delta B_{1FID} = 1.5\ pT \qquad \text{and} \qquad \delta B_{N=5} = 300\ fT \ .$$

In shot noise limit we may achieve $\delta B_{N=5} = 60\ fT$.

For 30% duty cycle



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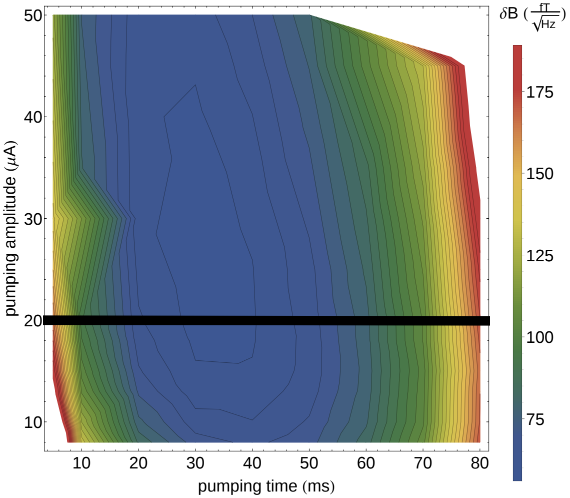
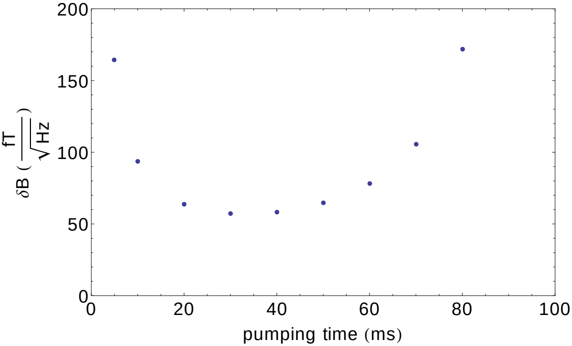


For 30% duty cycle

The highest sensitivity can be reached for a pump amplitude of $\approx 20\mu A$.



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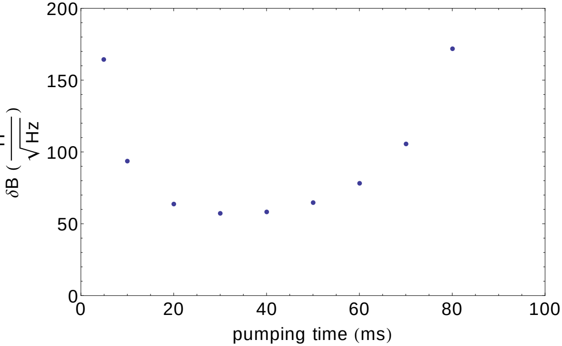
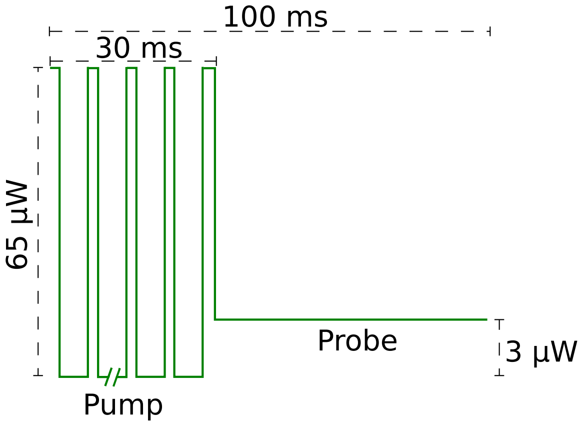


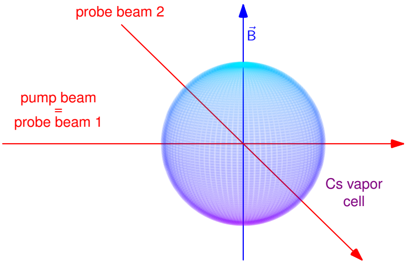
The highest sensitivity in shot noise limit we get is $\delta B = 60 \ \frac{fT}{\sqrt{Hz}}$.

Optimal parameters



The duty cycle of the pump waveform has to be 30%.

Investigation of systematic effects



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