An improved pilot bunch-based spin phase-lock feedback system for the measurement of the deuteron electric dipole moment

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Overview

Introduction: precursor run with the RF Wien filter

- The RF Wien filter is fully operational with a total power of up to $P = 1.5\,\mathrm{kW}$:
    - vanishing Lorentz force
    - spin rotation
- Induce and measure beam oscillation with mismatched RF Wien filter
    - $\vec{E}$ and $\vec{B}$ amplitude mismatch
    - $\vec{E}$ and $\vec{B}$ phase mismatch
- Multi-harmonic operation at

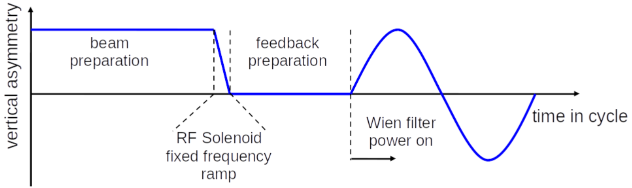
$$K = -1 : 871\,\mathrm{kHz}\,, \qquad K = +1 : 630\,\mathrm{kHz}\,,$$
$$K = -2 : 1621\,\mathrm{kHz}\,, \qquad K = +2 : 1380\,\mathrm{kHz}$$

In connection to other JEDI achievements:

- accurate spin tune measurement
- long spin coherence time
- **phase-lock feedback loop** to run the RF Wien filter in resonance

Current phase-lock feedback

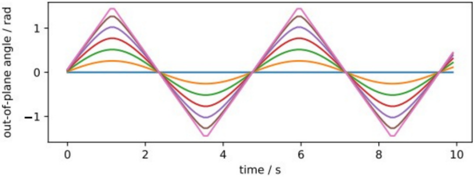
The basic workflow of the Phase lock feedback system

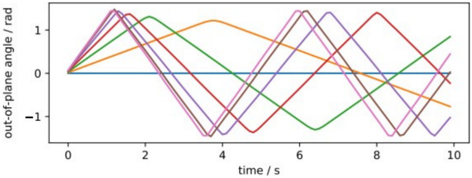


- adjust Wien filter frequency to spin precession frequency: $f_{\text{WF}} = f_{\text{Spin}}$
- adjust and maintain relative phase

Current phase-lock feedback

Simulation of the phase-lock feedback

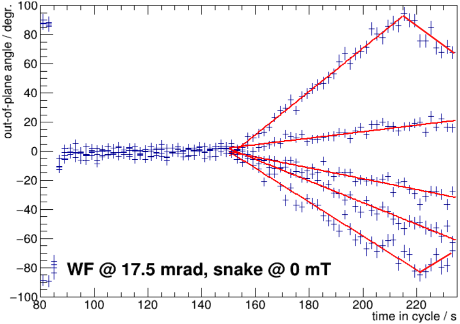




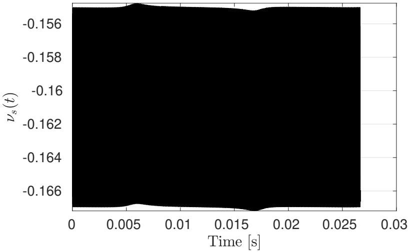
With feedback being turned on, the slopes of the slow oscillations are preserved but not the frequency

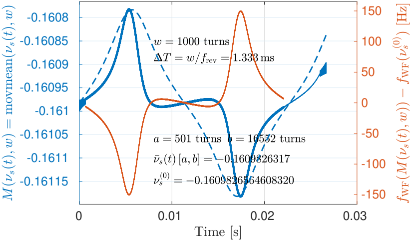
Current phase-lock feedback

A measurement example of the vertical polarization build-up with the phase-lock feedback turned on



Running spin tune



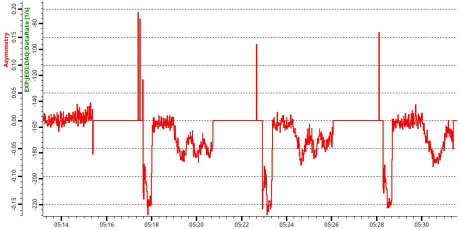


Running the RF Wien filter **continuously** on resonance requires continuous measurement of the spin tune

Observations with current feedback implementation

- results large extremum range between -0.166 and -0.156
- corresponds to a frequency variation is too large to be true
- measuring the *in-plane* spin precession while the fields of the RF Wien filter are oscillating does **not** strictly correspond to the spin tune, but rather to the **running** spin tune.

Halting the feedback loop

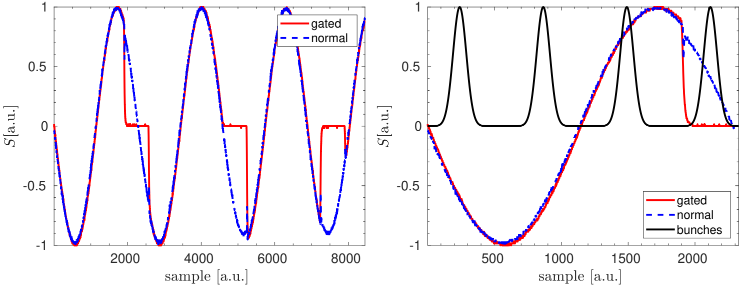


- the spin precession frequency is measured for a short time
- set the frequency of the Wien filter only once (not continuously)
- an irregularly shaped sinusoidal signals appeared

Conclusion

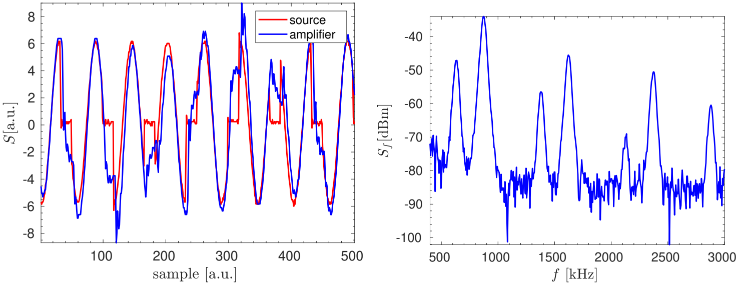
- it seems that the feedback system is producing undesirable effects on the measurements.
- when measuring the spin tune, the RF Wien filter should be switched off

An improved phase-lock feedback loop



- multi-bunch beam structure (4 bunches beam has been tested)
- the fields of the RF Wien filter will be visible to only three of four bunches
- leads to a RF field-free bunch, also known as pilot bunch
- the spin tune will be only measured using the pilot bunch
- the feedback system continuously maintains the spin precession frequency

Implementation



- the amplifiers are not designed as wideband as required for the precursor experiment
- modification of the amplifiers is in progress

New Hardware: 8-channels signal generator

New 8-channels signal generator

Improvements

- allows independent and synchronous operation of each amplifier independently
- more homogeneous feeding RF signal
- more homogeneous fields
- a window for a new frequency systematic analysis

Request

- For the experiment, it is sufficient to run the RF Wien filter in the so-called 90° mode, *i.e.*, vertical electric field and radial magnetic field. We require at least 1×10^9 vertically polarized deuterons at $970\,\mathrm{MeV}/c$. We would like to observe driven spin oscillations on all the bunches except the pilot one.
- The new feedback system shall be used to determine the frequency of the polarization which can be used to determine the EDM resonance strength. Upon success, all four frequencies of the RF Wien filter will be tested as well.
- For this investigation **we would like to request 1 week of machine development time and 1 week of measurement time**, to be tentatively scheduled at the end of the 4^{th} quarter 2019 (November/December).

Question?