LOW FIELD ONLINE NMR FOR HYPERPOLARIZED RARE GASES: SETUP AND CHARACTERIZATION

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<u>Purpose</u>

For the production of hyperpolarized ^{129}Xe gas, low-field online NMR setups are commonly used to optimize and control the parameters for spin exchange optical pumping (SEOP) [1-4]. Although all systems work at similar resonance frequencies (10 kHz < f_0 < 200 kHz) they have distinct features. Our aim was to implement active Q-switching (yielding a short 'dead time' after the B_1-pulse) for the online NMR setup, combined with a home-made electronic layout using simple off-the-shelf components. Here, we describe this circuitry in detail and describe how absolute ^{129}Xe polarization can be determined by comparison to ^{1}H signals, while carefully considering the tip angle distribution of the surface T/R-coil in use. The measurements are supplemented by theoretical calculations to allow for optimal ^{1}H and ^{129}Xe signals comparison.

<u>Methods</u>

The system comprises just three hardware components: a hand-wound transmit-receive coil (600 turns, 33 mm OD), a home-made analog circuit (adapted from [1]), and a commercial multi I/O card controlled by a PC program. An overview of the implementation within our mobile ^{129}Xe polarizer and the signal analysis of our NMR system are given in [4].

The circuit (Fig. 1) contains analog amplifiers for RF transmission and signal acquisition as well as electronics to perform the Q switching. The RF excitation pulse generated by the multi I/O card is fed into the current amplifier (OPA543T). A pair of crossed diodes is placed at the input and output of the amplifier to prohibit noise to be fed into the receive amplifier during data acquisition. The Q switch consists of a field effect transistor (FET) and its driving electronics. During a high level TTL pulse from the multi I/O card the FET is in saturation mode, thus putting a variable resistor (R1) in parallel to the resonance circuit resulting in a very low Q ~ 1. In receive mode the FET is open and the coil has a Q of ~ 14. During RF excitation the two last receive amplifiers (out of four, OP27CZ) are actively muted by a TTL pulse from the multi I/O card via two fast switches (MAX319). The gain of the three last stages can be switch between 3 and 21. A modest band-pass filter is placed between the stages 2 and 3. The output of the preamplifier is fed to the 16 bit ADC of the multi I/O card. For ^{1}H and ^{129}Xe measurements the identical coil is used, in the same position and under identical conditions (f_0 = 40 kHz) [4]. For ^{129}Xe a single-shot acquisition is sufficient, while 6000 averages are needed for ^{1}H to obtain similar signal-to-noise. As we used a small surface coil the B_1 field was strongly varying within the sample. To ensure the identical distribution of the tip angle for both nuclei we measured the ^{1}H and ^{129}Xe NMR signals in dependence of the B_1 pulse length.

<u>Results and Discussion</u>

With increasing B_1 pulse length the signal for each species increases initially similarly as with a volume coil (Fig. 2 purple line). But once the 90° condition is exceeded, the signal reduction from the spins next to the coil is at least partially compensated by additional contributions from spins farther away. Therefore, the observed signal stays close to its maximum, relatively independent of the applied B_1 pulse length. As shown in Fig. 2, the small surface coil acts almost identically on both ^{129}Xe and ^{1}H samples, except that the RF pulses for ^{129}Xe must be $\gamma_H/\gamma_{Xe} = 3.87$ times longer than for ^{1}H. Hence by working with pulse lengths yielding maximum signal for each nucleus (τ_H ~ 0.5 ms, τ_{Xe} ~ 1.8 ms) it is assured that the relative signal intensity for ^{129}Xe and ^{1}H solely depends on spin density and polarization. This is confirmed by an analytical calculation based on the vector potential and reciprocity algorithm to model signal vs. tip angle for our coil geometry. The result reproduces the ^{129}Xe signal for all pulse lengths up to 4 ms (Fig 2 red line).

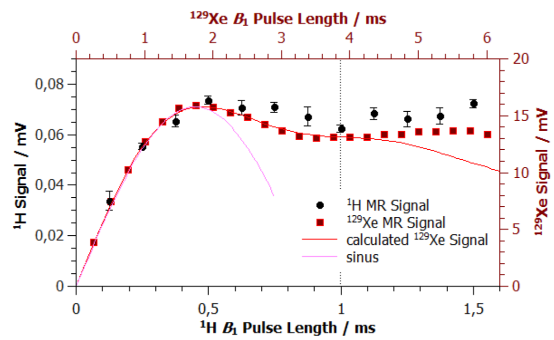

Figure 2: ^{1}H and ^{129}Xe low field NMR measurements (f_0=40 kHz) and analytical calculation of the ^{129}Xe signal

<u>Conclusion</u>

An easy-to-replicate system has been built for detecting signals from hyperpolarized gases as well as from thermally polarized protons in water. It was shown that reliable conditions can be found to cross calibrate the experimental ^{129}Xe signal with the ^{1}H signal from thermally polarized water, thus enabling the deduction of absolute ^{129}Xe polarization.

<u>References</u>

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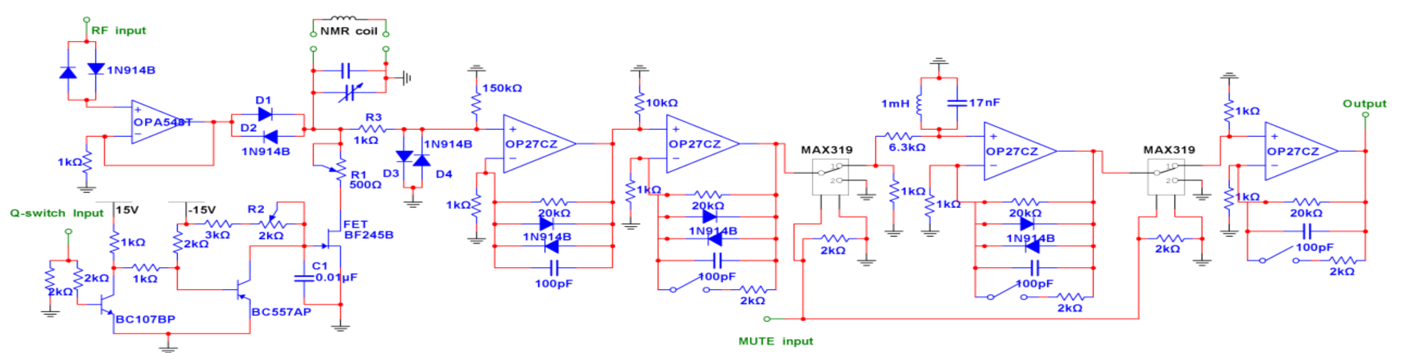

Figure 1: Circuit diagram for the low field online NMR setup (comprising: RF excitation current amplifier, active Q switch and four stage signal amplifier)