Chapter 6

Future Work

6.1 Hyperpolarized Gas Polarimetry

Although ^{129}Xe EPR polarimetry produced detectable EPR frequency shifts, the uncertainty associated with the shift was at least 50%. To develop ^{129}Xe EPR into a reliable polarimetry method, the following improvements have to be done:

1. The background field variation has to be reduced. To achieve an accuracy of 2%, the maximum allowable variation in the background EPR frequency–assuming a net ^{129}Xe EPR frequency shift of around 1 kHz–would be 20 Hz. Since γ_{Rb} = 466.7 kHz/G, the 20 Hz variation in ^{129}Xe EPR frequency would be produced by a variation in the background magnetic field on the order of 4×10^{-5} G. Consequently, for a holding field of 20 G, the field would have to be stable to ppm levels.

2. The intensity of Rb D2 resonance has to be increased. This could be achieved by increasing the cell's temperature during the EPR polarimetry measurement. If a temperature of 150°C instead of 80°C is used, the intensity of Rb D2 resonance may increase by a factor of around 100. However, if the higher pumping temperature significantly reduces the lifetime of hyperpolarized ^{129}Xe in the cell, then the detected Rb D2 resonance signal will have to be increased electronically (using RF amplifiers and filters).

3. The lifetime of the ^{129}Xe cell has to be improved. We speculated that the decay of the ^{129}Xe EPR signal–while the magnetization was anti-aligned with the magnetic field–was due to the poor lifetime of the cell, which caused the magnetization to decay towards its thermal equilibrium along the magnetic field axis. If the lifetime

of the cell is improved to 10 min, then the magnetization may take around 7 min ($\ln 2/0.1$ s) before decaying to zero. An EPR frequency shift measurement could easily be performed in that time frame.

A side note: The fact that the laser is pumping in the opposite direction while the gas is anti-aligned with the field becomes important only when $\gamma_{SE} \approx \Gamma$. For ^{129}Xe, $\gamma_{SE} \approx 10^{-4}$ s^{-1} at 90°C, so the lifetime of the cell would have to be around 2.8 h before the polarization of laser light during the AFP flip starts to matter.

6.2 Hyperpolarized Gas Imaging

While the uncertainty in the extrapolated ^{129}Xe T_2 relaxation times was only a few percent, the uncertainty in ^{3}He T_2 relaxation times was around 20%. To reduce the uncertainty in ^{3}He T_2 relaxation times, more measurements of ^{3}He T_2^{CPMG} relaxation should be performed, especially for the interecho times up to 30 ms. During these measurements, special care will have to be taken to eliminate the possibility of gas flow inside the cell (e.g., wait until cell cools to room temperature before collecting the data).

While our theoretical as well as experimental results show a significant improvement in the SNR of the image when using central ordering of phase-encode gradients, this might no longer be the case when imaging an object containing high-frequency components. Our model of diffusion-induced losses should thus be applied to, and tested on, an object with sharp edges (such as a cylindrically-shaped cell).

To obtain a 2-D spin echo image of hyperpolarized gas, diffusion-induced losses have to be minimized. This can be achieved by constructing a pulse sequence which collects central k-space data first (such as a progression of concentric circles) or/and by increasing the strength (while reducing the duration) of the imaging gradients. Note that the magnetic field gradients cannot be increased pass the point at which the concomitant terms start to dominate over the holding magnetic field. When imaging at low magnetic field strengths, this limiting gradient strength might easily be reached. Alternatively, we can conclude that the need for stronger imaging gradients increases the ideal imaging field strength. On the other hand, diffusion losses in the background gradients are reduced at smaller imaging field values. Therefore, the need for smaller background inhomogeneities decreases the ideal imaging field strength. It is therefore worth investigating whether the two opposing requirements converge to a single field strength. If so, it would also be worthwhile to compare this limiting field strength with the field strength at which the body-noise starts to dominate over the coil-noise (for a specific coil), which is the ideal field strength from the SNR perspective.