Development of a low-field spectrometer for in-situ polarisation measurements at 150 kHz

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Introduction

The calibration and optimisation of the spin-exchange optical pumping apparatus has previously been carried out by measuring the degree of ^{129}Xe polarization in the MR scanner. However this procedure is subject to a number of potential pitfalls. Not least there exist a number of areas where losses may occur. It would therefore be advantageous to be able to measure the polarisation at the point of production, i.e. within the optical cell

We have implemented a low field NMR spectrometer that is attached to the pumping cell for measurement of the polarisation in-situ (1-2). This is a commercially available Resonance Instruments apparatus with an operating frequency range of 0-20 MHz. We have optimised this to carry out low-field measurements of the ^{129}Xe polarisation at 150 kHz.

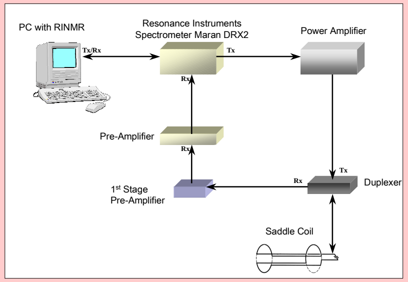
In this poster we demonstrate the calibration of this apparatus employing the ^{1}H signal from water. The observation of a water signal is confirmed in the first instance by removing the sample and further validated by varying the current in the Helmholtz and observing the subsequent shift in the resonance frequency.

We also recorded the ^{129}Xe signal from within the cell employing a single scan. The linewidth is shown to be governed largely by the homogeneity of the Helmholtz coil which was measured using a triple axis Hall probe.

The polarisation in the cell, employing the thermal signal from a known quantity of water was found to be about 60%. In contrast the polarisation measured after distillation and transport into the MR scanner was about 10%.

Spectrometer configuration

Below is shown a schematic representation of the low-field NMR spectrometer. It is driven by a PC which is connected to the Resonance Instruments spectrometer. We have constructed a saddle coil which is dual transmit/receive coil and is connected through a home built duplexer. The transmitter output from the spectrometer is 1 V which is amplified to 30 V for the RF pulse. The 1st stage pre-amp is optimised for low frequency detection and affords an additional 25 dB gain.

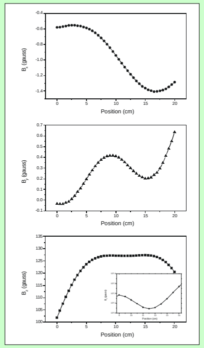


Characterisation of Helmholtz coils

Field profiles have been measured for our Helmholtz coils employing a triple axis Hall probe. The value of the x, y, and z components of the magnetic field were measured as a function of the z position

The profile along the centre of the coils i.e. z (bottom) is the most important factor in determining the NMR response.

The homogeneity along the z axis is ~0.1 gauss.

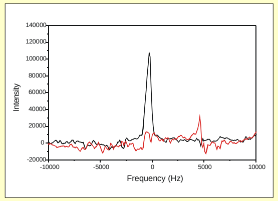


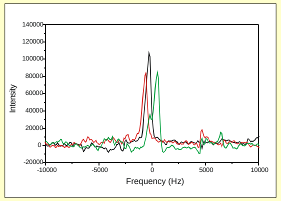
Calibration on ^{1}H signal in H_2O

Below shows the water signal recorded with 1024 scans. The B_0 field was 35.2 gauss corresponding to a frequency of 150 kHz.

Left shows the spectrum recorded with (black) and without (red) the water sample.

Right shows the water signal recorded at different B_0 field strengths by varying the current in the Helmholtz coil.



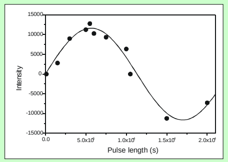


Pulse calibration

Pulse calibration was performed (right) by measuring the intensity of the water signal as a function of pulse duration.

From the fit (right) the ^{1}H 90° pulse was 57 µs.

The ^{129}Xe pulse length was calculated using this value and taking into account the ratio of the gyromagnetic ratios for proton and xenon.

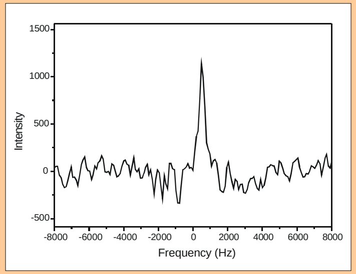


Single-scan ^{129}Xe spectroscopy in-situ

Below is shown a single scan spectrum of ^{129}Xe recorded within the pumping cell. The field strength was 128 gauss corresponding to a frequency of 150 kHz.

The width at half height is about 400Hz and is consistent with the homogeneity of the Helmholtz. This suggests that the linewidth is largely governed by T_2*.

The ^{129}Xe polarisation was measured inside the cell by comparing the integrated signal below to that of a known quantity of water and was measured to be about 60%.



Conclusion

We have demonstrated the use of a low-field NMR spectrometer for the measurement of the ^{129}Xe polarisation inside the pumping cell. This was found to be about 60% compared to a polarisation of about 10% as measured after transport into the MR scanner.

These results suggest that a large proportion of the polarisation is lost when transporting the ^{129}Xe from the SEOP apparatus to the MR scanner. This may suggest future engineering improvements that can be made to the pumping apparatus.

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References

1) W. Shao, G. Wang, R. Fuzesy, E. W. Hughes, B. A. Chronik, G. C. Scott, S. M. Conolly, A. Macovski, Appl. Phys. Lett. **80**, 2032-2034 (2002).
2) N. J. Shah, T. Unlu, H.-P. Wegener, H. Halling, K. Zilles, S. Appelt, NMR in Biomed. **13**, 214-219 (2000).