\[ ^3\text{He} \text{ NMR experiments at } \sim 7 \text{ G} \]

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1 \(^3\text{He} \text{ measurement using spin-echo pulse sequence} \]

Figure 1: A saddle coil (RF coil) \& Helmholtz-coil (receiver coil) with the 2" sphere \(^3\text{He} \text{ cell} \]

Figure 1 shows the current experimental setup. The pickup coil has a inductance of \( \sim 2.4 \text{ H} \). A inductor of \( \sim 110 \text{ mH} \) is connected in series to tune the resonance frequency around 24 kHz.

\( T_2 \) measurements:

- Run\#165: \( \pi/2 \) pulse, 421.9 us, F1 amp 44, F1 attn 12. Echo time: 40ms. \( T_2 \sim 416.9 \text{ ms} \).
• Run#218: \( \pi/2 \) pulse, 415 us, F1 amp 44, F1 attn 12. Echo time: 25ms. \( T_2 \approx 428.4 \) ms.

• Run#348: \( \pi/2 \) pulse, 415 us, F1 amp 44, F1 attn 12. Echo time: 50ms. \( T_2 \approx 470.6 \) ms.

• Run#350: \( \pi/2 \) pulse, 420 us, F1 amp 44, F1 attn 12. Echo time: 50ms. \( T_2 \approx 520.9 \) ms.

A pair of gradient coils are added. The settings on the APOLLO system: 20\( \times \)20 \( < - > \) 31.8 mG/cm, 20\( \times \)31.4 \( < - > \) 50 mG/cm, 40\( \times \)31.4 \( < - > \) 100 mG/cm.

**Imaging measurements:**

• Run#252: 0.1 G/cm gradient always on. Sinc pulse (for selecting a band, the whole cell) for 1.542 ms, phase modulation 00000...2222...00000...2222...0000. When the pulse is on, gradient 0.1G/cm. -0.1G/cm during the ring down for 3.855 ms. 2.313 ms with 0.1G/cm after the ring down. Acquisition for 200 ms. F1 attn=7. The FWHM in the FFT graph is XXXX Hz, equal to XXXX cm.

• Run#258: 0.1 G/cm, Sech pulse (Principles of nuclear magnetic resonance spectroscopy, page 110) with complicated phase is used since it can do a better Pi pulse with the gradient. First time trying sech pulse. F1 attn=20.

• Run#260: 0.1 G/cm, sech pulse, same as 258 with F1 attn=30.

• Run#261: 0.1 G/cm, did 10 times #260 (F1 attn=30) to find out the loss per measurement. loss261.eps \( - > \) loss=0.134 (30 degrees)

The hyperbolic secant pulse is given as

\[
A_{RF}(t) = B_1 \left[ \text{sech}(\beta t) \right]^{1+i\mu} \tag{1}
\]

• Where \( \beta = \frac{\pi \Delta f}{\mu} \), \( \Delta f \) is the frequency range, so our pulse time determines the frequency range. \( \mu = 5 \) gives a excellent 180° pulse[Callaghan]. In order to be used in the APOLLO, this sequence must be seperated into the absolute value and a phase by.

\[
A_{RF}(t) = |A_{RF}| e^{i\theta(t)} \tag{2}
\]

where

\[
\cos(\theta(t)) = \text{Re} \left( |\text{sech}(\beta t)|^{1+i\mu} \right) \tag{3}
\]

**Diffusion coefficient measurements:**
• Run#265: 0.1 G/cm gradient always on. First a 3.854 ms Sech $\pi/2$ pulse (attn=21) in Phase X. Wait for 1.927 ms. Another $\pi$ pulse (attn=15.2) for 3.854 ms in Phase Y. Wait for 2.908 ms and then acquire signal for 4.8 m. Repeat “$\pi$ pulse for 3.854 ms in Phase Y. Wait for 2.908 ms and then acquire signal for 4.8 m”. Using equations from XXXXX, diffusion coefficient = 1.17 cm$^2$/s.

• Run#266: Same as 265, but with 0.05 G/cm gradient always on. Diffusion coefficient = 1.58 cm$^2$/s.

• Run#267: Same as 265, but with 0.052 G/cm gradient always on and with the $\pi$ pulse phase flipped as Y, -Y, Y, -Y.... Diffusion coefficient = 1.50 cm$^2$/s.

With the Q-switch installed, the cable length becomes a little longer. The resonance frequency shifts from 24 kHz to 25.1 kHz.

Q switch and filter measurements:
• Run#305: 0.6 ms mute time with Q-switch (with oscilloscope disconnected), $\sim$8.55 degrees tip angle, 40 us long pulse, F1 amp 44, F1 attn 12. T1 measurement on a detachable cell. T1=16.3 hrs.

• Run#320: 0.75 ms mute time with Q-switch and filter with a gain of 1, $\sim$8.55 degrees tip angle, 40 us long pulse, F1 amp 44, F1 attn 12. T1 measurement on a detachable cell. T1=26.3 hrs.

Dilution setup measurements:
• Run#323: 0.75 ms mute time with Q-switch only (no filter), $\sim$8.55 degrees tip angle, 40 us long pulse, F1 amp 44, F1 attn 12. T1 measurement on the dilution setup cell. T1=220 minutes in the dilution cell after baking out.

If the $^3$He is let into the dilution cell directly, 51.8% of $^3$He will go in to the cell. Signal should be $\sim 50000 \times 0.518 = 25900$. However the APOLLO signal has dropped to $\sim 19000$. So $\sim 13.8\%$ $^3$He has lost its polarization during the transfer process.

• Run#326: no dilution, 2” spherical cell, $\sim$8.55 degrees tip angle, 40 us long pulse, F1 amp 44, F1 attn 12, no Q-switch, 2.5 ms mute time. signal = 43600.

• Run#327: $^3$He transferred to the cylindrical cell, 51.8% should be transferred. $\sim$8.55 degrees tip angle, 40 us long pulse, F1 amp 44, F1 attn 12, no Q-switch, 2.5 ms mute time. signal = 13302. (30.5% of run#326.)

• Run#328: $^3$He diluted from cylindrical cell using the 118 cc volume, 40% should be left in the cylindrical cell. $\sim$8.55 degrees tip angle, 40 us long pulse, F1 amp 44, F1 attn 12, no Q-switch, 2.5 ms mute time. signal = 6098. (45.8% of run#327.)

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Run#329: 3He diluted from cylindrical cell using the 118 cc volume again, 40% should be left in the cylindrical cell. ∼8.55 degrees tip angle, 40 us long pulse, F1 amp 44, F1 attn 12, no Q-switch, 2.5 ms mute time. signal = 2582. (42.3% of run#328.)

Run#358: transfer 3He from the spherical detachable cell into the cylindrical cell. Use the 1100 cc volume to dilute it 3.5% left in the cylindrical cell. Then use 420us Pi/2 pulse to do spin-echo. See a small FFT signal ∼2163 in the first echo. No signal further. (did not use the portable magnetic field)

Run#359: transfer 3He from the spherical detachable cell into the cylindrical cell twice. 51.8% × 51.8% = 26.8% left in the cylindrical cell, polarization unknown. use 420us Pi/2 pulse to do spin-echo. See signal in the first four echos. T2=85.2 ms. (did not use the portable magnetic field)

Run#365: The Faraday cage is made! transfer 3He from the spherical detachable cell into the cylindrical cell. Dilution factor 51.8% × 80/1180 = 3.4% left in the cylindrical cell, polarization unknown. use 420us Pi/2 pulse to do spin-echo. See signal in the first decay of the Pi/2 pulse. S/N=7270/500 ∼ 15. However the Pi pulse angle seems to be off. No echo seen. (did not use the portable magnetic field)

Run#366: transfer 3He from the spherical detachable cell into the cylindrical cell twice. Dilution factor 51.8% × 51.8% = 26.8% left in the cylindrical cell, polarization unknown. use 420us Pi/2 pulse to do spin-echo. See signal in the first decay of the Pi/2 pulse. S/N=12997/500 ∼ 26. However the Pi pulse angle seems to be off. No echo seen.

Run#379, T1 measurement after dilution at 3.5%. The faraday cage is put onto it and the signal lines are two separate BNC cables. The resonance frequency is 34.8 kHz. Pi/2 pulse is 305 us, mute time 2.5ms. Here we used 30 us@34.8 kHz for the T1 measurement every 10 minutes. loss=0.0123. T1=61.4+-5.2 mins fitted with a background.

Run#384, add Q-switch to the system, J112 FET and faraday cage. Noise level ∼250. close to the minimum of the APOLLO system. mute time 0.8 ms. resonance frequency 34.5 kHz. Try to calibrate Pi/2 pulse. Close to 335 us. Spin echo using Pi/2 and Pi pulses.

Run#390, Noise level ∼250. Mute time 0.8 ms. resonance frequency 34.5 kHz. dilute by a 0.246%. 100us pulse, loss=0.108. T1=10.8+-2.6 mins.

Run#392, Noise level ∼250. Mute time 0.8 ms. resonance frequency 34.5 kHz. dilute by a 0.1%. 120us pulse, loss=0.154. set the background to be 300, T1=4.3+-0.3 mins.

Run#413, Noise level ∼250. Mute time 0.8 ms. resonance frequency 34.5 kHz. dilute by a 0.246%. 100us pulse, loss=0.108. With no background fitting, T1=347 s. With bg fitting, T1=233 s.
• Run#414, Noise level ~250. Mute time 0.8 ms. resonance frequency 34.5 kHz. dilute by a 25%. spin echo measurement. See a big signal.

• Run#415, Noise level ~250. Mute time 0.8 ms. resonance frequency 34.5 kHz. dilute by a 0.1%. 120us pulse, 10 s interval, loss=0.154. With bg fitting, T1=49 s.

References