Low RF-field strength cross polarization combined with photo-induced non-persistent radicals for clinically applicable dDNP

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Low RF-field strength cross polarization combined with photo-induced non-persistent radicals for clinically applicable dDNP

Work in progress

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Cross Polarisation for SPINlab-like polarisers using non-persistent radicals is demonstrated.

The efficiency of the transfer from protons to carbon is modest at the currently achievable low B_1 fields of 4-5 kHz still yielding ^{13}C polarisation levels up to 15 %. Based on the presented results, we foresee polarisation levels superior to direct ^{13}C DNP in our next generation of double-tuned probes incorporating local tune and match.

Abstract

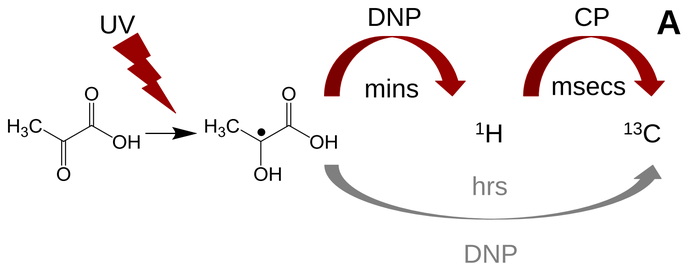
We demonstrate the possibility of ^{1}H Dynamic Nuclear Polarization followed by cross polarization to carbon (DNP-CP) using a modified low cost benchtop console (Kea2) equipped with an external amplifier (Tomco) and a SPINlab-like dissolution DNP polarizer *i.e.* using the same fluid path and allowing for hyperpolarisation of a full human dose. Cross polarisation (CP) using Laboratory Frame De- and Remagnetisation[1] (LAFDR) was found superior to alternative sequences at the limited B_1 fields employed. Faster build-up rates compared to ^{13}C DNP are demonstrated using TEMPOL (4-Hydroxy-2,2,6,6-tetramethylpiperidine 1-oxyl) and DNP-CP ^{13}C polarisations up to 15 % are achieved using non-persistent UV-induced radicals.

Introduction

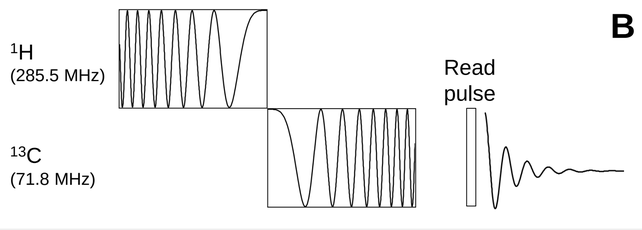
Dissolution Dynamic Nuclear Polarization (dDNP) is used to enhance the MR signals in imaging by factors of 10,000 [2] paving the road for metabolic MR studies. However, the polarization build-up on ^{13}C typically takes tens of minutes to hours, significantly lowering the versatility and throughput. Recently, studies have shown the possibility of speeding up the process by polarizing ^{1}H, which has a faster build-up, followed by polarization transfer to *e.g.* ^{13}C.[3] However, strong B_1 fields and small sample volumes are used, which makes the technique incompatible with clinical dDNP-MRI.
Moreover, for clinical use, and in general to eliminate the relaxation effect, the radical essential for DNP needs to be removed during dissolution. Use of pyruvic acid (PA) non-persistent photo-induced radicals for dDNP has been demonstrated to solve this issue[4] and recently polarization build-up on protons with τ_{DNP}~690 s and 70 % polarization has been presented[5].

Methods

Overview

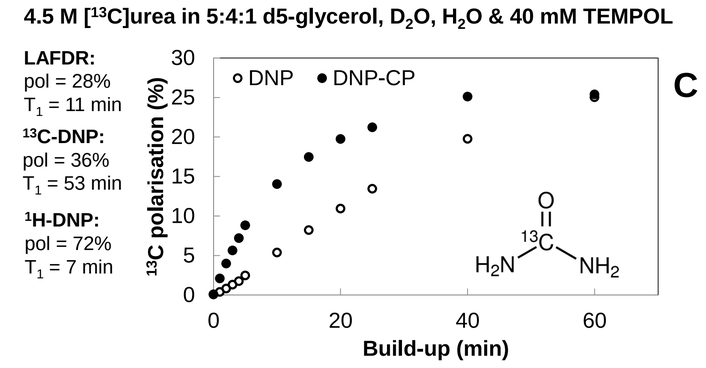


CP by Laboratory Frame De- and Remagnetisation (LAFDR)

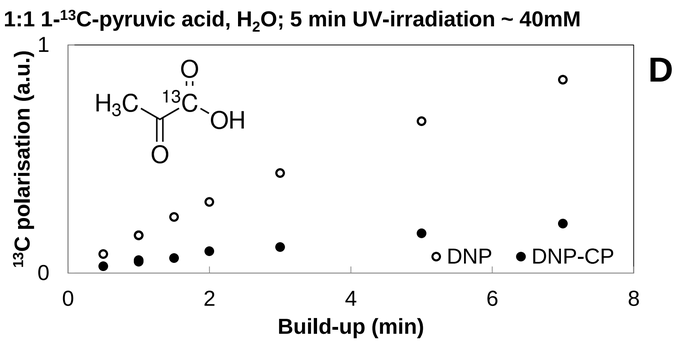


Experimental results

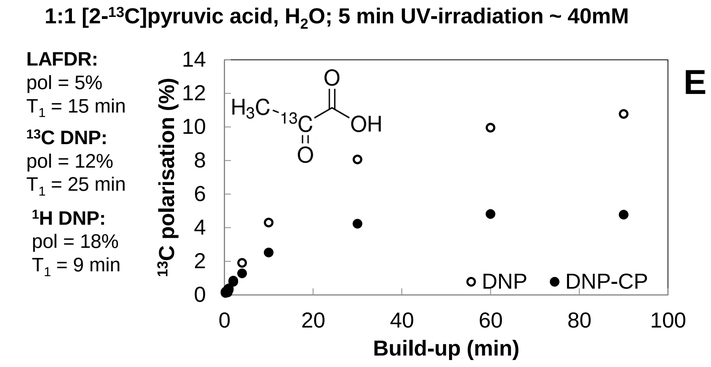
DNP-CP using TEMPOL as radical

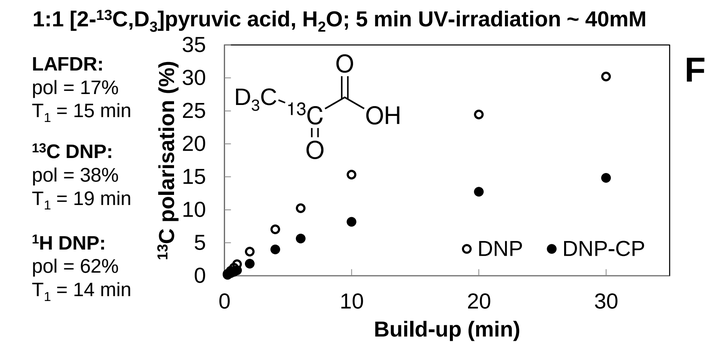


DNP-CP using UV-induced radicals



DNP-CP using UV-induced radicals with broadened linewidth due to hyperfine coupling





Results

The efficiency of DNP-CP depends on the build-up rate and final polarisation achieved on protons as well as the transfer efficiency of the CP sequence.

1. For $B_1 \leq 5$ kHz LAFDR (fig. **B**) was found to outperform other CP sequences (data not shown).
2. On the TEMPOL containing sample, DNP-CP using optimised LAFDR outperforms ^{13}C DNP for build-up times < 1 hour, and 20% ^{13}C polarisation was achieved in only 20 min (fig. **C**).
3. Using [1-^{13}C]PA as the substrate for non-persisting radicals gives a too narrow EPR-line for efficient ^{1}H DNP resulting in poor DNP-CP performance (fig. **D**).
4. Introduction of hyperfine coupling to the unpaired electron by ^{13}C labelling in position 2 increases the EPR linewidth yielding fast ^{1}H DNP build-up, but a polarisation of only 18 %, and therefore still inefficient DNP-CP (fig. **E**).
5. Deuterating the methyl group of PA increases the ^{1}H DNP polarisation to 62 % and maintains the efficiency of CP. This yields a final ^{13}C polarisation of 15% after CP (fig. **F**).

Conclusion and Outlook

We have demonstrated DNP-CP on a clinical-compatible SPINlab-like polariser using a low-cost benchtop console equipped with an external amplifier. Moreover, the technique has been combined with non-persistent UV-induced radicals. At the current state, with $B_1 \leq 5$ kHz, direct ^{13}C DNP still out-performs the DNP-CP. However, the goal is to implement local tuning of the probe to achieve sufficient B_1 fields to increase the transfer efficiency. We expect that sufficiently strong B_1 fields are achievable for this setup to outperform direct ^{13}C DNP both with respect to build-up rates and polarisation levels.

Acknowledgements

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