Hyperpolarization of flowing water by dynamic nuclear polarization

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Magnetic resonance angiography (MRA) is a technique for imaging blood vessels based on magnetic resonance imaging (MRI) for the evaluation of aneurysms, stenosis, occlusions, and so on. To obtain clear images, imaging time needs to be done for a long for signal averaging, and this makes the resolution, in particular of heart, worse due to the beating. To overcome this problem, the injection of polarized water into a blood vessel was demonstrated1). Both the imaging time and the resolution were improved through the use of this method. In this experiment, the polarized 1H spins in water were generated by dynamic nuclear polarization (DNP) method. The method can be used to polarize > 30% of 1H spins using cryogenics and sub-terahertz devices, however, about 90% of the polarization was relaxed before injection, due to the short spin-lattice relaxation time of 1H spins.2) In this work, we adopted the flow-DNP method to polarize 1H spins in flowing water for simplicity.

The DNP method is used to transfer electron spin polarization to nuclei with microwave irradiation. We applied it to flowing water (flow-DNP).3) This is a very compact, cheap, and versatile method for polarizing liquid-state samples. We would like to apply this method not only to MRA but also for various studies such as on proteins using high-resolution NMR system.4)

Experimental setup of flow-DNP is shown in Fig. 1. A microwave cavity with a frequency of 9 GHz is placed in the electromagnet. The external magnetic field is set at 0.3 T. Water is flowed into the cavity by a pump. The tube in the cavity is filled with gels functionalized with radicals to slow down the flow rate only inside the cavity. The microwave irradiates the radicals with an incident power of 3 W. Although the polarized water is looped back to the pump in the current setup, it will be sent to the MRI system in the future. The coil in the NMR is placed in the downstream direction of the cavity to check the polarization. The enhancement factor \( \varepsilon \) of the polarization is given as

\[
\varepsilon = 1 - \rho f s \frac{\gamma_e}{\gamma_n}
\]

where \( \rho \) is the coupling factor, \( f \) is the leakage factor, \( s \) is the saturation factor, and \( \gamma_e \) and \( \gamma_n \) are the gyromagnetic ratios of the electron and 1H, respectively. With the above setup, \( \rho, f, \) and \( s \) are estimated to be 0.07, 0.90, and 1, respectively,3) and the expected polarization is 0.0041 %.

References

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