Optically pumped magnetometers for ultra-low field relaxometry of polarized nuclear spins

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We present recent developments towards application of optically pumped magnetometers (OPM) for quantitative detection of nuclear spin relaxation in biological tissue at ultra-low magnetic fields (ULF NMR). The accurate estimation of the T_1 relaxation time provides information about local proton-binding conditions. This can be used, e.g. to distinguish between cancerogenous and benign tissue [1]. The decay constant is extracted from recording of sub-second long relaxation of the nuclear spin precession at frequencies of up to several hundred hertz at microtesla fields. For ULF NMR relaxometry typically highly sensitive SQUID magnetometers have been employed [2]. OPMs are non-cryogenic, can be compact and potentially are capable to substitute SQUIDs in ULF NMR. However common implementations are substantially limited with respect to required bandwidth and field range. Specific optimizations are needed to secure femtotesla sensitivity, high bandwidth, and short dead time. We evaluate several OPM designs, both commercially available and in-house developed, and report pilot measurements of the relaxation in water samples in a broad range of detection fields (Fig. 1).

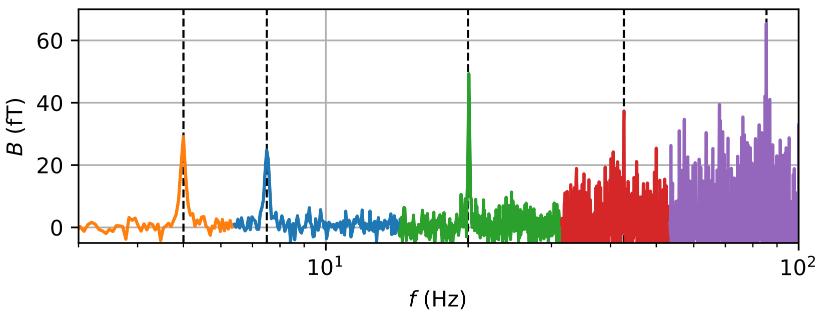

Figure 1. Combined spectra of the nuclear spin relaxation in a pre-polarized water sample, recorded at different fields with a custom feedback M_x-OPM. Total recording time 1280 s, OPM sensitivity 40 fT/$\sqrt{\text{Hz}}$. Vertical dashed lines denote the expected NMR peak positions.

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[2] S. Hartwig, H.H. Albrecht, H.-J. Scheer, M. Burghoff, and L. Trahms, A Superconducting Quantum Interference Device Measurement System for Ultra Low-Field Nuclear Magnetic Resonance, Applied Magnetic Resonance, **44**, 9-22 (2013).