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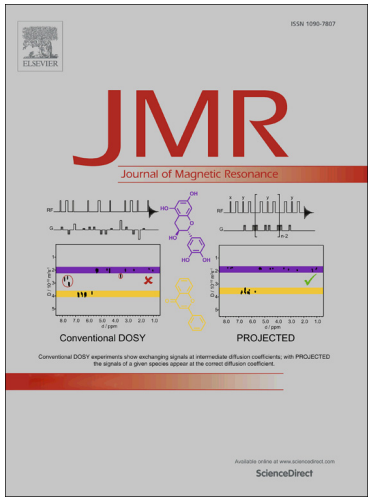

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Do twisted laser beams evoke nuclear hyperpolarization?

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The hyperpolarization of nuclear spins promises great advances in chemical analysis and medical diagnosis by substantially increasing the sensitivity of nuclear magnetic resonance (NMR). Current methods to produce a hyperpolarized sample, however, are arduous, time-consuming or costly and require elaborate equipment. Recently, a much simpler approach was introduced that holds the potential, if harnessed appropriately, to revolutionize the production of hyperpolarized spins. It was reported that high levels of hyperpolarization in nuclear spins can be created by irradiation with a laser beam carrying orbital angular momentum (twisted light). Aside from these initial reports however, no further experimental verification has been presented. In addition, this effect has so far evaded a critical theoretical examination. In this contribution, we present the first independent attempt to reproduce the effect. We exposed a sample of immersion oil or a fluorocarbon liquid that was placed within a low-field NMR spectrometer to Laguerre-Gaussian and Bessel laser beams at a wavelength of 514.5 nm and various topological charges.

We acquired ^{1}H- and ^{19}F-NMR free induction decay data, either during or alternating with the irradiation that was parallel to B_0. We observed an irregular increase in NMR signal in experiments where the sample was exposed to beams with higher values of the topological charge. However, at no time did the effect reach statistical significance of 95 %. Given the measured sensitivity of our setup, we estimate that a possible effect did not exceed a hyperpolarization (at 5 mT) of 0.14 - 6 %, depending on the assumed hyperpolarized volume. It should be noted though, that there were some differences between our setup and the previous implementation of the experiment, which may have inhibited the full incidence of this effect. To approach a theoretical description of this effect, we considered the interaction of an electron with a plane wave, which is known to be able to induce electronic (e.g. in Rubidium) and subsequent nuclear hyperpolarization. Compared to the plane wave, the additional transitions caused by a twisted wave are of the order of 10^{-3} less. This suggests that the twist of the laser is unlikely to be responsible for the hyperpolarization of nuclear spins, unless a new mechanism of momentum transfer is identified.

Keywords: nuclear hyperpolarization, low-field NMR, complex light, light-matter interaction