Monitoring the nuclear spin in helium-3 by Faraday interaction

Matteo Fadel[1], A. Serafin[2], Y. Castin[2], A. Sinatra[2], G. Tastevin[2], P. J. Nacher[2], and P. Treutlein[1]

[1] Department of Physics, University of Basel, Klingelbergstrasse 82, 4056 Basel, Switzerland
[2] Laboratoire Kastler Brossel, ENS-Université PSL, CNRS, Université de la Sorbonne et Collège de France, 24 rue Lhomond, 75231 Paris, France

Helium-3 atoms have a nuclear spin-1/2 that is very well isolated from the environment, and thus shows coherence times of hundred of hours. This property makes it a promising system for quantum technologies, with a number of possible applications ranging from quantum-enhanced sensors to quantum memories. So far, however, there is no experiment manipulating the nuclear spin of helium- 3 in the quantum regime. As a first step toward this goal, we report progress towards the optical read-out of the nuclear spin degree of freedom using Faraday measurement, where the interaction between light polarization and nuclear spin is mediated by metastable helium-3 atoms via metastability-exchange collisions. Reaching quantum-noise limited detection, and increasing the coupling strength, will allow us to prepare non-classical nuclear spin states via quantum nondemolition measurement [1,2].

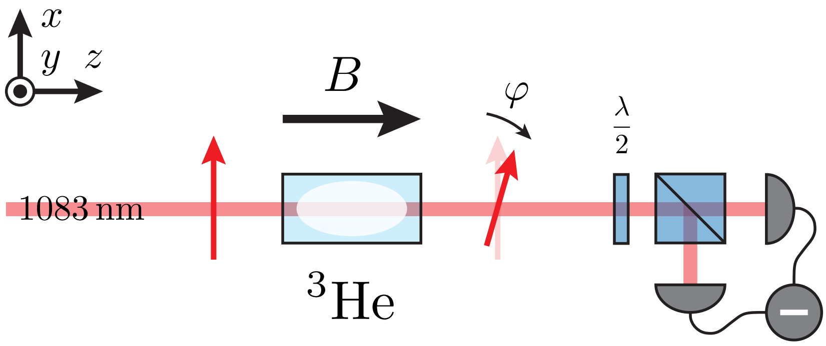

Figure 1. Illustration setup for monitoring the nuclear spin in a helium-3 vapor cell. Metastable helium atoms interact with the light, and lead to rotation in the light polarization through Faraday interaction. Homodyne detection of the light passed through the cell results in a measurement of the electronic spin state, that is mapped to the nuclear state via metastability exchange collisions with ground state atoms.

[1] A. Serafin, M. Fadel, P. Treutlein and A. Sinatra, Nuclear spin squeezing in helium-3 by continuous quantum nondemolition measurement, preprint at arXiv:2012.07216 (2020).
[2] A. Serafin, Y. Castin, M. Fadel, P. Treutlein and A. Sinatra, Nuclear spin squeezing by continuous quantum non-demolition measurement: a theoretical study, preprint at arXiv:2012.14686 (2020).