Nuclear-spin-based rotation sensing with diamond

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Recently, we demonstrated a solid-state rotation sensor based on ^{14}N nuclear spins intrinsic to nitrogen-vacancy (NV) centers in diamond [1]. This type of sensor detects rotation by measuring the shift in the precession rate of nuclear spins, analogous to vapor-based NMR devices. The sensor employs direct optical polarization and readout of the ^{14}N nuclear spins and a radio-frequency double-quantum pulse protocol that monitors ^{14}N nuclear spin precession, and it does not require microwave pulses resonant with the NV electron spin transitions. However, nuclear-spin-based rotation sensors are inherently sensitive to variations in the magnetic field, which produce changes in the precession rate similar to those produced by rotation, limiting the long-term stability of the device. This issue can be overcome by simultaneously measuring the precession of two spin species with different gyromagnetic ratios, which can be combined to obtain the rotation rate while canceling the contribution from magnetic field fluctuations.

In this work we implement this idea using a diamond containing two isotopes of nitrogen (^{14}N and ^{15}N) and simultaneously measure the precession rates of NV nuclear spins of both isotopes. We found that we were able to suppress the magnetic sensitivity of the rotation sensor by several orders of magnitude. Its performance is limited in part by the temperature dependence of nuclear spin transitions, which we have recently measured to be on the order of ~0.1 Hz/K [2]. This dependence can be canceled by monitoring temperature using the nuclear quadrupole splitting of the NV centers containing ^{14}N.

The nuclear spin interferometric technique developed in this work may find application in solid-state frequency references and in extending tests of fundamental interactions at micro- and nanoscale to those involving nuclear spins. With further improvements, it may also find use in practical devices such as miniature diamond gyroscopes for navigational applications.

References

[1] A. Jarmola, S. Lourette, V. M. Acosta, A. G. Birdwell, P. Blümler, D. Budker, T. Ivanov, and V. S. Malinovsky, "Demonstration of diamond nuclear spin gyroscope", Sci. Adv. **7**, eabl3840, 2021

[2] S. Lourette, A. Jarmola, V. M. Acosta, A. G. Birdwell, D. Budker, M.W. Doherty, T. Ivanov, and V. S. Malinovsky, "Temperature Sensitivity of ^{14}NV and ^{15}NV Ground State Manifolds," arXiv:2212.12169 [quant-ph]