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Optimizing Readout for Nuclear Magnetic Resonance Axion Searches

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Low-temperature Nuclear Magnetic Resonance (NMR) samples offer long-lived quantum states that are extremely sensitive to small perturbations from new physics, including interactions with axion dark matter. The sensitivity of NMR axion detectors is sometimes limited by the precision with which the magnetization of the spin state can be read out, especially when large geometric pickup coil inductances cannot be tuned because of geometric constraints. DC SQUIDs have been used for high-sensitivity readout of NMR samples, but their "energy sensitivity" is limited to a few quanta, such that $S_{\Phi\Phi}/2L = n\hbar$, where $n >\sim 1$. Flux sensors with better energy sensitivity (potentially better than $\hbar$) require a different readout paradigm. This work describes the Radio Frequency Quantum Upconverter (RQU), a quantum sensor which uses a dispersive readout scheme to allow better energy sensitivity. In the RQU, the low frequency (kHz-MHz) spin magnetization signal modulates the phase of a microwave readout tone. This scheme allows better energy sensitivity than is possible with DC SQUIDs for applications with untuned reactance, improving the sensitivity of NMR axion detectors.

Less than 5 years of experience since completion of Ph.D

Y

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