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Searching for time-varying nuclear electric dipole moments using precision magnetic resonance

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The Cosmic Axion Spin Precession Experiments (CASPEr) search for ultralight axion-like dark matter. CASPEr-e is sensitive to the time-varying nuclear electric dipole moment, induced by the electric-dipole moment (EDM) coupling g_d. The detection scheme is based on a precision measurement of ^{207}Pb solid-state nuclear magnetic resonance in a polarized ferroelectric crystal. We calibrated the detector and characterized the excitation spectrum and relaxation parameters of the nuclear spin ensemble with pulsed magnetic resonance measurements in a 4.4 T magnetic field. We swept the magnetic field near this value and searched for axion-like dark matter with Compton frequency within a 1 MHz band centered at 39.65 MHz. Our measurements place the upper bound $|g_d| < 9.5 \times 10^{-4}$ GeV^{-2} (95% confidence level) in this frequency range. This constraint corresponds to an upper bound of 1.0×10^{-21} e · cm on the amplitude of oscillations of the neutron electric dipole moment, and 4.3×10^{-6} on the amplitude of oscillations of CP-violating θ parameter of quantum chromodynamics. Our results demonstrate the feasibility of using solid-state nuclear magnetic resonance to search for axion-like dark matter in the nano-electronvolt mass range.

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