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Searching for spin-dependent exotic interactions with ferromagnetic microsphere-cantilever probes

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Spin-dependent exotic interactions may occur between two fermions through exchanging of hypothetical bosons, such as axions, Majorons, familons, Z'bosons, some of which may be candidates for dark matter particles. These interactions can be measured at the tabletop scale with high precision experiments, providing indirect experimental information about the mediators. Here, we report an experimental search for two exotic interactions, denoted V12+13 and V9+10, in the micrometer range using frequency-modulation atomic force microscopy. A cantilever is employed as a weak force sensor to measure the exotic interactions between nucleons in a density-modulated structure and spin-polarized electrons in a ferromagnetic microsphere glued at the end of the cantilever. During data acquisition, the ferromagnetic microsphere probe is driven to vibrate at its resonance frequency. When the cantilever is subjected to the V12+13 or V9+10 interaction, its amplitude or resonant frequency changes. If the exotic interactions exist, the probe will experience periodically varying forces as it passed over the masses of Au and SiO2 in the density-modulated structure, which results in periodic changes in the vibration amplitude or resonance frequency of the cantilever. Maps of the amplitude and resonance frequency are recorded simultaneously by scanning over the surface of the nucleon source at a certain distance. The maximum likelihood estimation method is used to analyze the data. The experiment sets a new limit on the V12+13 interaction in the interaction range from 0.7 um to 5 um, the coupling constant g_A^e g_V^N at λ = 1.3 um should not exceed 4.8×10^(-15). The limit on the V9+10 interaction is also given in the interaction range from 0.2 um to 40 um, the coupling constant (g_s^N g_p^e)ℏc should be less than 5.5×10^(-17) at λ = 4.0 um.

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