Search for spin dependent exotic interactions using mechanical sensors and magnetic structures

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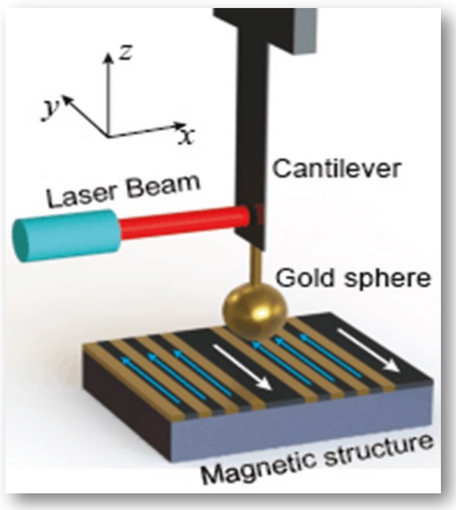
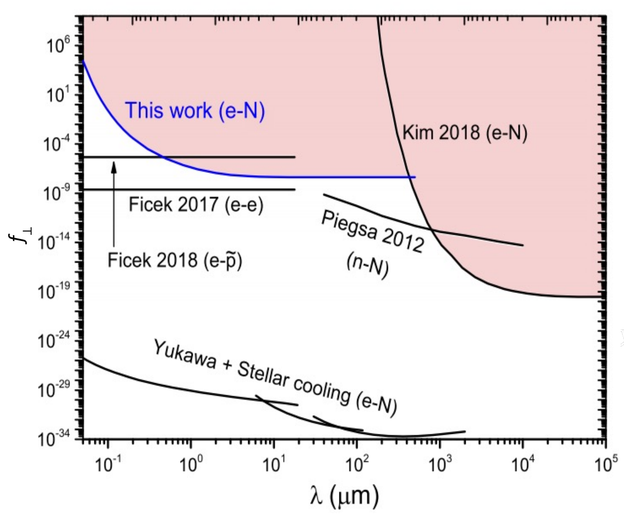
Abstract Extensions to the Standard Model often introduce new bosons that can mediate exotic spin-dependent interactions. The hypothetical bosons, including axions, majorons, dark photon, Z′ bosons etc., may be candidates for dark matter particles. Searching for such spin-dependent interactions can extract important information about the bosons, such as the mass and the coupling strength with the Standard Model particles, thus providing an indirect approach for exploring dark matter particles. Here we present the experiments to search for spin dependent exotic interactions with mechanical sensors. These interactions may be mediated by spin-1 bosons, such as the generic Z′ boson. Mechanical sensors are used to measure the force between a nucleon source and a spin-polarized electron source (magnetic structure). To distinguish between the exotic interaction and the electromagnetic forces, the spin-polarized electron sources or nucleon sources are specially designed to generate space-modulated exotic interaction signals with a constant electromagnetic force background. Based on the preliminary experimental data, stronger constrains on the exotic interaction are given.

V_{4+5} Detection

$$V_{4+5} = -f_{\perp}^{eN}\frac{\hbar^2}{8\pi m_e c}[\hat{\sigma}\cdot(\vec{v}\times\hat{r})]\left(\frac{1}{\lambda r}+\frac{1}{r^2}\right)e^{-\frac{r}{\lambda}}$$





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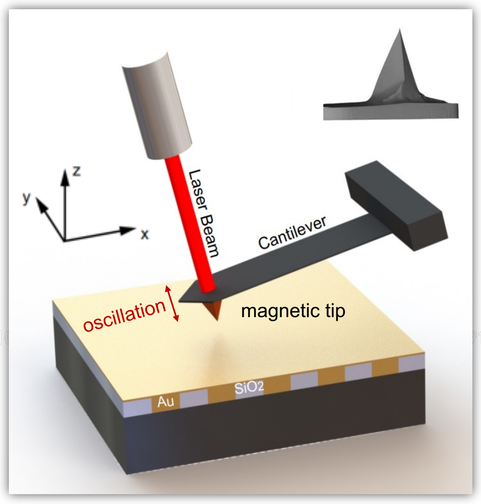
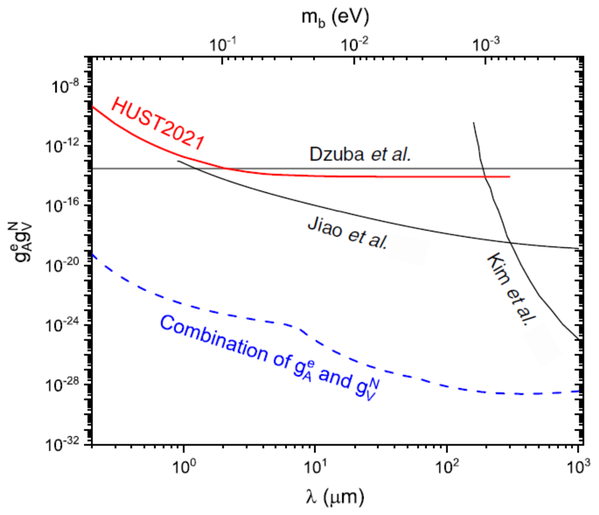
V_{12+13} Detection

$$V_{12+13} = g_A^e g_V^N \frac{\hbar}{4\pi}(\hat{\sigma}\cdot\vec{v})\left(\frac{1}{r}\right)e^{-\frac{r}{\lambda}}$$





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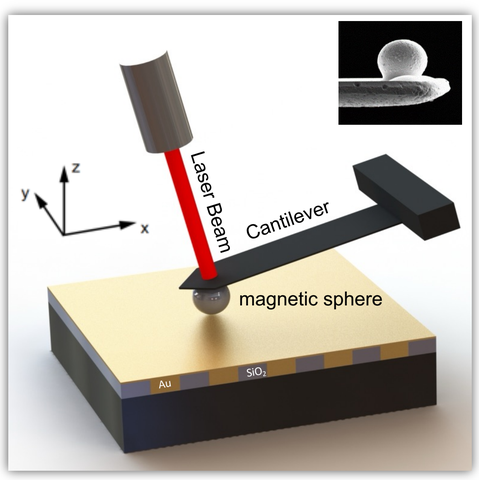
Principle



Nucleon source: Au / SiO_2

Spin-polarized electron source:

NdFeB sphere

Displacement measurement:

Laser interferometer

V_{12+13} signal:

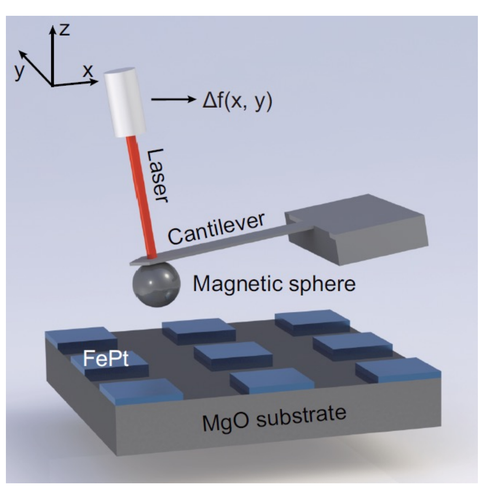
$$z_{amp} = z_0\left(1+\frac{Q\omega_0}{k}\frac{F_{12+13}}{v}\right)$$

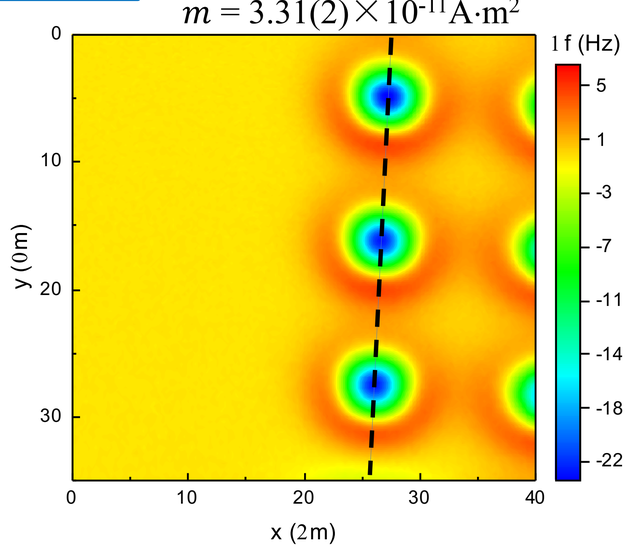
(k = 8.13(33)N/m, f_0 = 134.64(3) kHz, Q = 1928(25), F_{noise} = 9.1×10^{-15} N/$\sqrt{\text{Hz}}$)

Magnetic moment calibration

$$\Delta f = G_x m_x + G_y m_y + G_z m_z + \Delta f_0$$

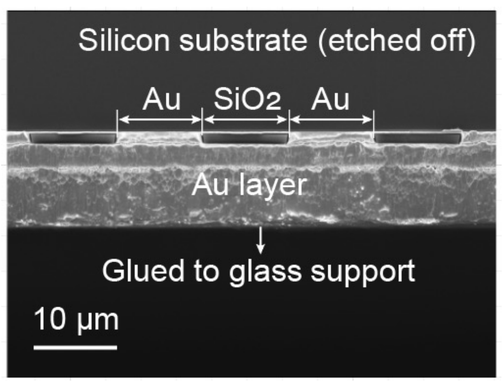
$$m = 3.31(2)\times10^{-11}\,\text{A}\cdot\text{m}^2$$



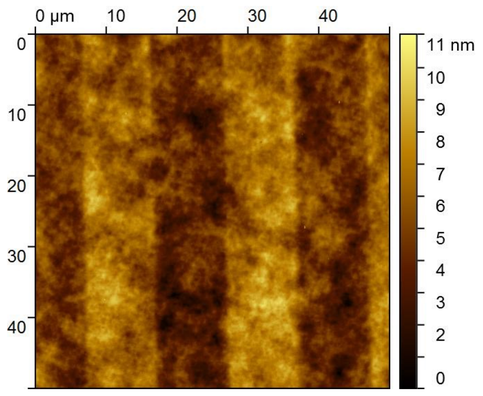


Density modulation nucleon source

SEM image of the cross-section



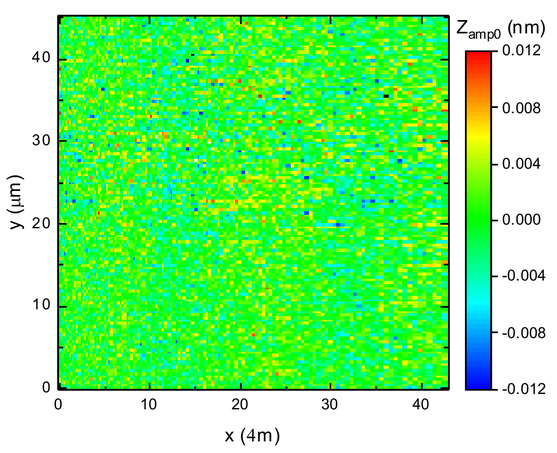
AFM image of the surface



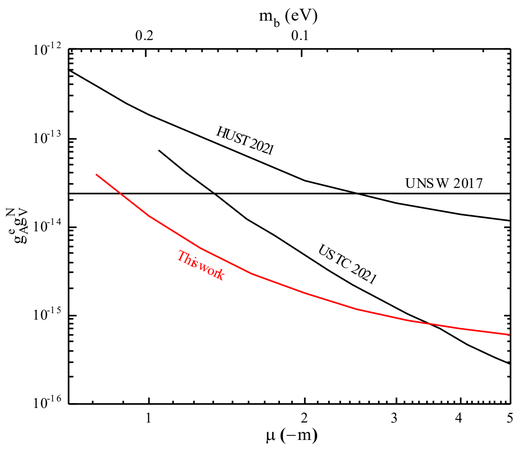
Surface corrugation: 2 nm

Experimental result

Map of Z_{amp}



Constraints on the coupling constant



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