Ultra-high precision search for exotic interactions

December 6 2021, by Liu Jia

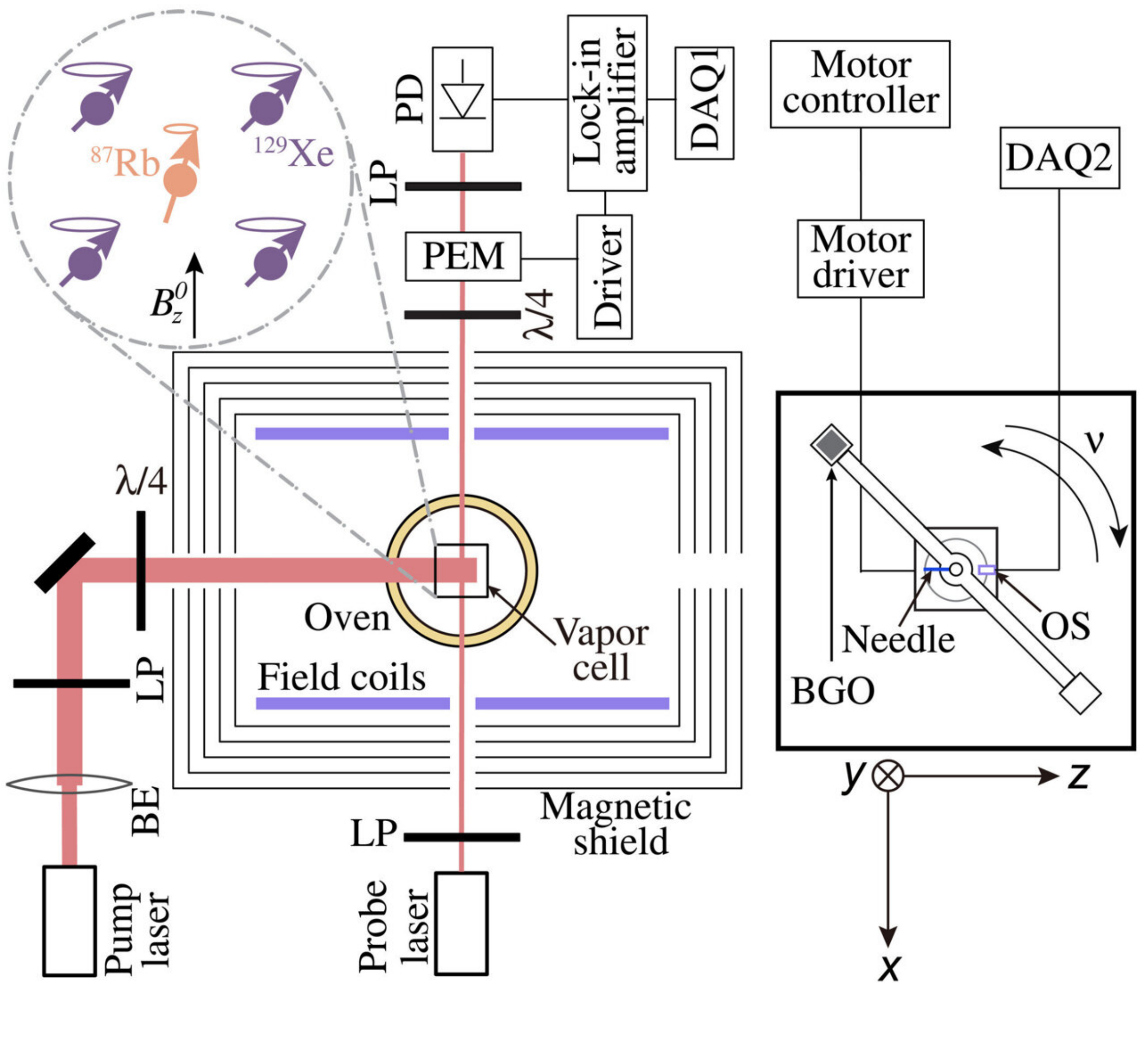

Fig. 1. Experimental setup.The ^{87}Rb magnetometer uses a 0.5-cm^3 cubic cell consisting of 5 torr isotopically enriched ^{129}Xe, 250 torr N_2 as buffer gas, and a droplet of ^{87}Rb. The vapor cell is placed inside a five-layer cylindrical μ-metal

shield to reduce the ambient magnetic field. A bias field B0zzˆ is applied along z to tune the ^{129}Xe Larmor frequency to $\nu_0 \approx 4.995$ Hz. The ^{87}Rb spins are polarized by optical pumping with 795-nm D1 light. ^{87}Rb-^{129}Xe spin-exchange collisions polarize ^{129}Xe spins to ~30% (40, 47). The x component of ^{87}Rb spins is measured via optical rotation of a linearly polarized probe beam (54–57), which is blue-detuned 110 GHz to ^{87}Rb D2 transition at 780 nm. The right inset shows the configuration of a bismuth germanate insulator [$Bi_4Ge_3O_{12}$ (BGO)] mass and a motor. A single BGO mass at the end of an aluminum rod rotates with frequency $\nu_0 \approx 4.995$ Hz to generate the spin- and velocity-dependent interactions. BE, beam expander; LP, linear polarizer; λ/4, quarter–wave plate; PD, photodiode; PEM, photoelastic modulator; DAQ, data acquisition; OS, optoelectronic switch. Credit: DOI: 10.1126/sciadv.abi9535

The standard model is currently recognized as the most successful theory for studying particles and their interactions. However, it still fails to account for some important astronomy observations, such as the existence of dark matter and dark energy. Physicists generally believe that there are new particles beyond the standard model, which transmit new interactions between standard model particles. Due to the weak effect of exotic interaction, searching for exotic interactions is extremely challenging, and it is urgent to explore new methods to improve experimental sensitivity.

In a study published in *Science Advances*, the research team led by Prof. Peng Xinhua from University of Science and Technology of China of the Chinese Academy of Sciences, collaborating with Prof. Dmitry Budker from Helmholtz Institution, realized ultra-high precision search of exotic spin- and velocity- dependent interactions beyond the standard model, and amplified the magnetic field signal of exotic interactions at least two orders of magnitude and applied the technique to the investigation of exotic velocity-interactions based on their newly developed quantum spin-based amplifier.

In this study, the researchers rotated a high-density $Bi_4Ge_3O_{12}$ (BGO) crystal at high speed to induce the interaction between the BGO crystal and the xenon nucleus in the spin-based amplifier. This exotic interaction is equivalent to generating an alternating oscillating magnetic field on the nucleus, so the measurement of the exotic interaction can be converted into a magnetic field detection. The quantum spin-based amplifier can amplify the magnetic field to be measured at ultra-low noise levels, which greatly improved the sensitivity of the exotic interaction search.

Given the possible interference of technical noise, researchers took advantage of the velocity dependence of the exotic interaction to effectively eliminate the interference signals such as vibration and classical magnetic field.

They found no evidence of the existence of new particles in the search area, and thus proposed a new class of bosons-nucleus coupling constraint, which was at least two orders of magnitude bigger than that of the previous international optimal constraint.

This study demonstrated the unique advantages of the spin-based amplifier to study new physics theories beyond the standard model.

More information: Haowen Su et al, Search for exotic spin-dependent interactions with a spin-based amplifier, *Science Advances* (2021). DOI: 10.1126/sciadv.abi9535

Provided by Chinese Academy of Sciences