High Precision Low Energy Measurements for Detecting Dark Matter and Testing Fundamental Physics

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The mass of axion dark matter is only weakly bounded by cosmological observations, necessitating a variety of detection techniques and experiments at many different mass ranges. Axions are expected to couple to photons via the inverse Primakoff effect and cryogenic resonant cavities are often proposed as a tool for detecting these photons. We present first results and future plans for the **O**scillating **R**esonant **G**roup **A**xio**N** (ORGAN) experiment, a microwave cavity axion haloscope situated in Perth, Western Australia designed to probe for high mass axions motivated by several theoretical models [1]. The first stage focuses around 26.6 GHz in order to directly test a claimed result, which suggests axions exist at the corresponding mass of 110 μeV. Later stages will move to a wider scan range of 15-50 GHz (60–210 μeV). We present the results, which sets a limit on $g_{a\gamma\gamma}$ of 2.02 × 10^{-12} eV^{-1} at 26.531 GHz, or 110 μeV, in a span of 2.5 neV with 90% confidence. Furthermore, we outline the current design and future strategies to eventually attain the sensitivity to search for well-known axion models. This includes new designs of tunable microwave cavities based on Bragg modes, with super mode tuning [2].

Plans are presented to search for low mass axions below 10^{-6} eV [3,4]. Resonant cavity haloscopes are inherently narrowband and the range of possible axion dark matter masses spans several orders of magnitude. On the other hand broadband low-mass particle haloscopes have been proposed using inductive magnetometer sensors coupled to SQUID amplifiers and requiring a solenoid magnet of gapped toroidal geometry. In this work we propose an alternative approach, which uses a capacitive sensor in a conventional solenoidal magnet with the magnetic field aligned in the laboratory z-axis, as implemented in standard haloscope experiments. In the presence of a large DC magnetic field, the inverse Primakoff effect causes a time varying electric field (or displacement current) in the z-direction to oscillate at the axion Compton frequency. We propose non-resonant techniques to detect this electric field by implementing capacitive sensors coupled to a low noise amplifier. We present the theoretical foundation for this proposal, and the first experimental results. Preliminary results constrain $g_{a\gamma\gamma}$ to 2.35×10^{-12} GeV^{-1} in the mass range of 2.08×10^{-11} to 2.2×10^{-11} eV, and demonstrate potential sensitivity to axion like dark matter with masses in the range of 10^{-12} to 10^{-8} eV.

We also demonstrate technological improvements in phonon sector tests of Lorentz Invariance that implement quartz Bulk Acoustic Wave oscillators [5]. In this experiment, room temperature oscillators with state-of-the-art phase noise are continuously compared on a platform that rotates at a rate of order a cycle per second. The discussion is focused on improvements in noise measurement techniques, data acquisition and data processing. Preliminary results of the second generation of such tests are given, and indicate that SME coefficients in the matter sector can be measured at a precision of order 10^{-16} GeV after taking a years worth of data. This is equivalent to an improvement of two orders of magnitude over the prior acoustic phonon sector experiment [6].

References

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