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High and low mass axion haloscopes at UWA

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The Frequency and Quantum Metrology (FQM) group at UWA is in the process of constructing a haloscope experiment (ORGAN) designed to probe for axions at 26.6 GHz. The motivation for this search is to perform the first direct test of the Beck result [1] which suggests axions exist at this frequency. There are many technical issues and optimisations that must be considered in the design of such a high mass axion haloscope, which are typically considered infeasible. We have developed new techniques to increase the sensitivity of such searches. These new techniques were motivated by a rigorous theoretical treatment of axion haloscope theory, where the detecting structure differs from a right cylindrical cavity embedded centrally in a magnetic field [2]. By examining such systems in detail we found that the common assumption of equal electric and magnetic axion-resonant photon couplings is incorrect in any system which is not centrally symmetric with respect to the applied external magnetic field. When considering explicitly the magnetic coupling of axions to resonant photons, it is possible to achieve improved sensitivity by employing novel cavity geometries and experimental setups. We discuss the ORGAN experiment and how it will employ these techniques to improve sensitivity. A further consequence of the explicit treatment of the axion magnetic coupling is the possibility of sensitive low mass axion haloscopes employing lumped 3D LC resonators (known commonly as re-entrant cavities [3,4]), with separated magnetic and electric fields. Such structures resonate at frequencies inherently lower than those achievable in an empty cavity. In these systems it is critical to explicitly treat both the axion electric and magnetic couplings in order to accurately calculate sensitivity. We present a proposal for such a low mass haloscope.

[1] C. Beck, Phys. Rev. Lett. 111, 231801 (2013), http://link.aps.org/doi/10.1103/PhysRevLett.111.231801.

[2] B. T. McAllister, S. R. Parker, M. E. Tobar, Phys. Rev. Lett (accepted, in production).
N.B: Longer pre-print version available on arXiv. https://arxiv.org/abs/1512.05547

[3] Y. Fan, Z. Zhang, N. Carvalho, J.-M. Le Floch, Q. Shan, and M. Tobar, IEEE Transactions on Microwave Theory and Techniques 62, 1657 (2014), arxiv.org/abs/1309.7902.

[4] J.-M. Le Floch, Y. Fan, M. Aubourg, D. Cros, N. C. Carvalho, Q. Shan, J. Bourhill, E. N. Ivanov, G. Humbert, V. Madrangeas, and M. E. Tobar, Review of Scientific Instruments 84, 125114 (2013), http://dx.doi.org/10.1063/1.4848935.

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