Date:	**Thursday, 29 November 2018**
Time:	**11:00 – 12:20**
Speaker:	**Michael TOBAR**
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Title:

Axion Dark Matter Detectors at UWA and Australian Plans for Dark Matter Particle Physics

Abstract:

Attached

Notes:

Axion Dark Matter Detectors at UWA and Australian Plans for Dark Matter Particle Physics

ME Tobar, M Goryachev, BT McAllister, G Flower, EN Ivanov, J Bourhill, C Thomson

First, we will discuss the current status of the Oscillating Resonant Group AxioN (ORGAN) experiment at the University of Western Australia [1]. The goal of ORGAN is to search for the range of masses proposed by the SMASH model [2]. This will include a review of progress and results to date, then cover developments in cavity design and R&D, and the next science run of the primary haloscope experiment. The experiment will operate in a new dedicated BlueFors-XLD1000 dilution refrigerator with a base temperature of 7 mK and a 14 T superconducting solenoid. Both have been ordered and will arrive in June 2019. Cavity R&D builds on our work on tunable super-mode dielectric resonators [3]. These resonators can be designed to have scan rates improved by 1 to 2 orders of magnitude over traditionally tuned haloscope resonators. We will also briefly mention our current plans for an Australian Centre of Excellence for Dark Matter Particle Physics, which is short listed for funding.

Second, we present a new approach to axion detection based on precision frequency measurements [4], which utilizes a high Q-Factor cavity supporting two mutually orthogonal modes. We demonstrate how axion modified Maxwell equations lead to either a beam splitter or parametric interaction terms in the axion up or down conversion cases respectively. The term couples two modes of different frequencies with the axion frequency/mass being either the difference (up conversion) or sum (down conversion) of mode frequencies. We propose to measure the frequency shifts associated with the axion coupling Hamiltonian terms. Based on the equation of motion of axion coupling modes, we calculate the frequency shifts that can be observed. We predict both real and imaginary parts to be sensitive to axions depending on the type of coupling. The potential of the new approach relies on the fact that unlike in the power detection method where the sensitivity is limited by the thermal (or quantum) noise in the readout, the frequency sensing method is limited by resonator linewidths and their internal fluctuations. A bench top dual-mode oscillator based on a copper cylindrical cavity has been constructed with the TM_{020} mode at 9 GHz, and the TE_{011} mode tunable in the 6-9 GHz range. Both modes have Q-factors on the order of $0.5\text{-}1\text{x}10^4$ and mode overlap coefficients of order unity. The phase noise has been characterized and limits will soon be set. For modern cryogenic resonators quality factors exceed 10^9 giving fractional frequency stability better than 10^{-16} [5] and further implementation of low noise techniques [6] means that the axion-photon couplings at the predicted axion couplings can in principle be reached.

Thirdly, we have developed some unique ultra-strong coupled ferromagnetic cavities in our laboratory [7-8], much stronger than has been implemented recently for axion detection [9]. The 'Ferromagnetic haloscope' exploits the coupling between axions and electrons in the form of collective spin excitations of magnetic materials with readout through a microwave cavity. We present a more general theoretical treatment in a Hamiltonian framework with coupled magnons and photons. In particular, we analyze operation in the dispersive regime, which allows easy tuning of axion mass parameter space. The first experiment was implemented in a cryogenic setup, and initial results are presented setting laboratory limits on the axion-electron coupling strength of $g_{a\gamma\gamma}>3.7\ 10^{-9}$ in the range $33.79\ \mu\text{eV} < m_a < 33.94\ \mu\text{eV}$ with 95% confidence.

Finally, and more controversially we have shown that the axion modified electrodynamics can be represented as additional magnetically induced electric polarization and electrically induced magnetization in the constitutive relations, with the axion induced bound electric current and charge linked by the continuity equation [8]. For the rich vacuum of QCD, microscopically we can interpret this effect as oscillating vacuum dipoles, which macroscopically behave as a polarization field and a displacement current. The modified Lorentz force on charges due to vacuum polarization was previously calculated by J Hong and JE Kim [9], which can be interpreted as an electromotive force or a non-conservative component to the electric field.

We have also come up with some more complicated methods to improve sensitivity to axions, however these enhancements are probably not practical for broad axion searches, but once found could be implemented to improve sensitivity [13-14].

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