Contribution ID: **328** Type: **Poster**

Exploration of Wire-Array Metamaterials for the Plasma Axion Haloscope

Wednesday 29 March 2023 19:10 (1 minute)

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Recent theoretical work predicts the mass of the post-inflation axion to lie above 40μeV (˜10 GHz) [1], higher than where microwave cavity experiments can effectively reach, owing to the steeply decreasing volume of the cavity with frequency. It has recently been proposed to circumvent this limitation by replacing the microwave cavity with a wire-array metamaterial whose plasma frequency is determined by its unit cell rather than its boundary conditions, i.e. its size, as is the case with conventional microwave cavities [2]. Thus in principle it is possible to build a resonator that could be both arbitrarily high in frequency and arbitrarily large. We have performed initial investigations of the feasibility of this concept by microwave transmission measurements (S_{21} scattering parameter), data from which we extract the plasma frequency, loss term and effective width; based on these results we can project quality factors Q > 10,000 for a resonator at cryogenic temperatures [3]. More recently we have carried out a study of the plasma frequency as a function of unit cell parameters demonstrating a dynamic range in frequency usable in an axion haloscope.

This work supported under NSF Grants No. PHY-1914199 and PHY-2209556.

1- M. Buschmann et al., Nature Communications 18, 1049 (2022).
2- M. Lawson, et al., Physical Review Letters 123, 141802 (2019).
3- M. Wooten, et al., Annalen der Physik (accepted for publication, 2023), arXiv:2203.13945v3

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Session Classification: Reception and Poster Session in the same room

Track Classification: Axions, Alps, Wisps as dark matter