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Microwaves with a twist: helical resonators for a new form of ultra-light darkmatter detection

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Chirality is a fundamental property in many physical systems ranging from particle physics, topological and quantum systems, complex molecules and chiroptical phenomena. Many of these phenomena occuras surface states, at high energy and frequency, due to complex meta structures or plasmonic systems,which inevitably add loss. In this work we realise a new class of resonator, the Anyon cavity resonator,based on twisted and Möbius structures, which exhibit bulk chiral modes at radio frequencies with near unity helicity. We show that the modes naturally couple strongly to ultra-light dark matter axions with near unity form factors, equal to the square of the mode helicity. Ultra-light axions have been shown to solve the Standard Model strong Charge-Parity problem [1] and could account for the entire dark matter density of the universe [2], and are usually searched for using putative axion interactions with gluons and neutrons [3]. In contrast, ultra-light dark matter axion experiments proposed through the axion-photon chiral anomaly require two near degenerate photon modes, and are limited by how close in frequency the two modes can be tuned [4]. We show, due to the unique resonator properties, modes with non-zero helicity interact with the ultra-light axions causing an amplitude modulation, without the need for two seperate photon modes. This not only drastically reduces the complexity, but also opens up the possibility of utilising low loss superconducting resonators [5], allowing sensitive searches in the ultra-light mass range of 10−22to 10−14eV.

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