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Towards a Cavity Haloscope with a GHz Tuning System Using Galvanically Contacted Transmon Qubits

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A critical challenge in cavity haloscope experiments is the development of fast and wide-range frequency tuning systems. One promising approach is to incorporate qubits based on DC SQUIDs into the cavity, where the qubit-cavity interaction is controlled by an external magnetic flux [1]. This non-mechanical method is particularly attractive for fast scanning, as it avoids the frictional heating that limits conventional tuning systems. Our previous work on the DarQ-Lamb experiment also demonstrated a search for dark photon dark matter using this tuning system with a tunable transmon qubit [2, 3]. However, in these previous studies, the frequency tuning ranges were limited to the order of 10 MHz [1, 2], primarily because the qubit-cavity interaction was not fully optimized for wide tuning.

This presentation discusses strategies to broaden the tuning range of such a cavity tuning system. This improvement is crucial for expanding the mass search range for dark matter. We report on the progress of a cavity haloscope with galvanically contacted transmon qubits. This approach is designed to achieve a strong qubit-cavity coupling regime, which is expected to enable a GHz-scale frequency tuning range.

[1] F. Zhao et al., (2025), arXiv: 2501.06882

[2] K. Nakazono et al., (2025), arXiv: 2505.15619

[3] K. Nakazono et al., (2024), 19th Patras Workshop on Axions, WIMPs and WISPs (Oral talk).

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