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Photon frequency conversion in high-Q superconducting resonators: axion electrodynamics, QED, and nonlinear meissner radiation

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Bogorad et al. proposed Superconducting Radio-Frequency (SRF) cavities with high quality factors as a platform for detecting axions, which are a dark matter candidate, as well as low-energy QED corrections that give rise to photon-photon scattering [1]. The idea is to use the cubic nonlinearity of axion-electrodynamics to detect the axion field by measuring photons at a signal frequency ω3 = 2 ω1 - ω2 in an SRF cavity simultaneously pumped with photons at two resonant frequencies ω1 and ω2. Signal photons are sourced by axion-mediated currents, or by virtual electron-positron pairs in the vacuum of the cavity [1,2]. However, the Meissner screening current is a nonlinear function (nonlinear Meissner effect [NLM]) of the field at the surface, and thus sources photons at the signal frequency ω3 [3]. We report calculations of the number of NLM photons, leakage noise photons, and the resulting impact on the sensitivity of SRF cavities to axion and QED mediated photon conversion [4]. For SRF cavities with ultra-high-Q we show that the NLM effect parametrically shifts the frequency of surface generated photons sufficiently away from the signal frequency to allow for detection of nonlinear QED frequency conversion. We also show that dual-cavity setup for source and detector [5] and the single-cavity setup proposed for heterodyne detection of galactic axion dark matter [6] can suppress the NLM and leakage backgrounds.

I have read and accept the Privacy Policy Statement

Yes

Footnotes

[1] Z. Bogorad et al., Phys. Rev. Lett. 123, 021801 (2019).
[2] W. Heisenberg and H. Euler, Z. Phys. 98, 714 (1936).
[3] J. A. Sauls, Prog. Theor. Exp. Phys. 2022, 033I03 (2022).
[4] H. Ueki and J. A. Sauls, Prog. Theor. Exp. Phys. 2024, 123I01 (2024).
[5] C. Gao, and R. Harnik, J. High Energ. Phys. 2021, 53 (2021).
[6] A. Berlin et al., J. High Energ. Phys. 2020, 88 (2020).

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Author: UEKI, Hikaru (Louisiana State University)

Co-author: SAULS, James (Louisiana State University)

Presenter: UEKI, Hikaru (Louisiana State University)

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