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Search for axion dark matter with a transmon-based photon counter

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We report about a significant advancement in the search speed of axion dark matter with cavity-based haloscopes. Our approach combines a 3D cavity with a transmon-based single microwave photon counter (SMPD) devised to detect itinerant photons, a circuit-QED architecture compatible with the strong magnetic fields required for axion-to-photon conversion.
In the SMPD, an incoming photon is converted to a qubit excitation via a four-wave-mixing process, and the overall efficiency of the detection process in the present device is about 50%. The SMPD is cyclically operated following a measurement protocol that allows for tuning of the cavity frequency to probe different axion masses, beyond monitoring with metrological methods the power from the cavity as well as the background.
In the reported pilot experiment we use a hybrid surfaced cylindrical NbTi-copper cavity mounted to the based stage of a dilution refrigerator. With the 2 Tesla magnetic field we apply during the experiment, the cavity maintains a high quality factor, of about a million for its axion-sensitive mode TM010, and it can be tuned by a triplet of sapphire rods controlled by a cryogenic nanopositioner.
We demonstrate a remarkable 20-fold enhancement in the search speed compared to quantum-limited linear amplifiers, and report a new axion-photon coupling limit of $g_a < 7 \times 10^{-14}$ GeV^{-1} over a frequency window of 0.4 MHz centered around 7.36 GHz.

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