

Quantum-enhanced dark matter searches using cat states

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Dark photon is one of the potential dark matter candidates with compelling cosmological origins and favorable extensions of fundamental physics beyond the Standard Model. Haloscope experiments are underway to detect the bosonic candidate by exploiting its weak couplings to the resonating electromagnetic fields in microwave cavities. Quantum metrology enables sensitive haloscope dark matter searches, particularly using nonclassical electromagnetic states, such as cat states featuring sub-Planck interference structures in phase space. Here, we present the first experimental application of four-component cat states within a high-quality superconducting microwave cavity to detect dark photons. We demonstrate an 8.1-fold enhancement in the signal photon rate and constrain the dark photon kinetic mixing angle to an unprecedented $\epsilon < 7.32 \times 10^{-16}$ near 6.44 GHz (26.6 μeV). By employing a parametric sideband drive to actively tune the cavity frequency, we achieve dark photon scan searches and background subtraction across multiple frequency bins, yielding a sensitivity at the 10^{-16} level within a 100 kHz bandwidth. Our cat-state-assisted search scheme demonstrates a substantial improvement over previous results, promising potential implications in quantum-enhanced searches for new physics.

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