Dynamical Casimir effect in a Josephson metamaterial

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A feat of the quantum theory of fields is that vacuum fluctuations have experimentally testable consequences. To calculate the ground-state wave function of a system one needs to specify the boundary conditions, and the theoretical prediction is that a mere, rapid change of boundary conditions in time can result in a measurable amount of energy being created (Dynamic Casimir effect, DCE). Indeed, the boundary conditions are responsible for the well-known static Casimir effect, in which vacuum fluctuations between two plates result in an attractive force. While there exists convincing experimental evidence for the static Casimir effect, the DCE has remained elusive so far. Recently, it was recognized that modulation speeds approaching effectively the velocity of light can be obtained in a circuit quantum electrodynamics setup in which the boundary condition is realized using a flux-tunable SQUID loop at the end of a superconducting coplanar waveguide. Instead of a single SQUID, we use a metamaterial consisting of an array of 250 SQUIDs, which allows us to change the boundary conditions at frequencies around 10 GHz at a modulation strength corresponding to a distance variation on the order of 0.1 mm. As expected by theory, we find creation of large amounts of noise, i.e. photon creation, even at temperatures where the field modes are essentially thermally unoccupied. Moreover, we have investigated correlations at frequencies about half of the pump frequency, and find characteristic behavior predicted for the DCE.

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