Quantum Metasurfaces as Probes of Vacuum Particle Content

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The quantum vacuum of the electromagnetic field is inherently entangled across distinct spatial sub-regions, resulting in entangled particle content across these sub-regions. However, accessing this particle content in a controlled laboratory experiment has remained out of experimental reach. Here we propose to overcome this challenge with a quantum mirror made from a two-dimensional sub-wavelength array of atoms that divides a photonic cavity. The array's response to light is tunable between transmissive and reflective states by a control atom that is excited to a Rydberg state. We find that vacuum photon content from non-perturbative changes of the boundary conditions and therefore distinct spatial sub-regions of the vacuum causes subtle frequency shifts that are accessible to sub-wavelength atom array platforms. This novel approach for probing vacuum particle content stems from the system's unique ability to create coherent dynamics of superpositions of transmissive and reflective states, providing a quantum-enhanced platform for observing vacuum particle creation from highly non-perturbative boundary condition changes of the electromagnetic field vacuum.

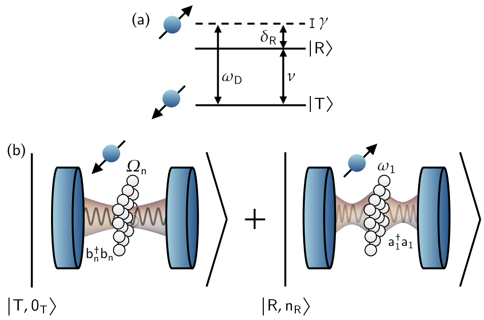

Figure 1: