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Random-Defect Laser: Manipulating Lossy Two-Level Systems to Produce a Circuit with Coherent Gain[1]

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Random two-level system (TLS) defects in dielectrics absorb energy and limit the coherence of superconducting quantum devices including qubits and resonators used in quantum computing applications. So far attempts to reduce this loss have been confined to device design and material optimization. In the present work we demonstrate the ability to control the loss of a dielectric by directly manipulating the population of its TLSs using a uniform swept dc electric field and two AC pump fields. The swept field shifts the TLS energies through a fixed-frequency pump field resulting in an inversion of the TLS population. After the sweep, the TLSs are brought into degeneracy with the resonator where they emit photons. The emission is found to be dependent on individual cavity-TLS interactions, and the narrowing linewidth at increasing photon occupancy indicates stimulated emission. Characterization with a microwave probe shows a transition from ordinary defect loss to negligible microwave absorption, and ultimately to coherent amplification. Thus, instead of absorbing microwave energy, the TLSs can be tuned to reduce loss and even amplify signals.

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