Spin-based magnetic imaging of superconducting microwave metamaterials

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Quantum simulation, the process of studying well-controlled model quantum systems can help us gain insight about complex quantum phenomena. Our goal is to develop an integrated hybrid quantum system for analog quantum simulation. Coupled cavity arrays (CCAs) can serve as a powerful architecture for engineering the photonic environment for quantum simulation applications, for example they can be used to implement topological lattices [1], Dirac cones [2], flat bands [2], or non-Euclidean geometries [3]. Arrays of compact lumped-element microwave (MW) resonators based on high kinetic inductance disordered superconducting thin films offer a versatile platform for implementing CCAs due to high design freedom and robust fabrication process [4].

We use weakly coupled nitrogen-vacancy (NV) centers in diamond as microwave detectors [5] to image the MW field amplitude and direction in compact NbTiN superconducting resonators. This will provide direct insights into the spatial profiles of photonic eigenmodes in a 1D / 2D arrays of subwavelength cavities. The freedom in designing the resonators and the couplings, combined with the small footprint allows us to study interesting MW photonic metamaterials exhibiting flat bands or topologically protected states that could have useful applications for quantum technologies. In the future, engineering strong coupling between the NV ensembles and the resonators will allow us to study collective emission effects and the interaction of spin ensembles with artificial photonic environments.

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