Metamaterials and quantum metamaterials for controlling microwave propagation

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Recently it has been proposed that intriguing phenomena such as Bloch oscillations, artificial gauge field and nonlinear effects for photons can be realized in coupled resonators. In this study, novel planar metamaterials based on the hybrid structure consisting of double split ring resonator and complementary split ring resonators are studied by experiment and finite element simulations. We demonstrate that they behave as negative refraction index metamaterials at resonance. The photonic band can be continuously tuned from gapless to gapped, ensuring the slow wave property at the band edge. By changing the orientation of the resonators, it is found the microwave propagation has a great change in the effective hopping phase. We discuss the possible orientation texture in a two-dimensional array leading to exotic phenomena, such as artificial gauge field.

We also theoretically study the transmission properties of electromagnetic waves propagating in open Cooper-pair boxes(CPB) system. Formed by regularly assembled artificial atoms, quantum metamaterials are proposed to exhibit electromagnetic resonance as well as quantum coherence so as to yield great advances in quantum optics. Implemented with a Fabry-Perot cavity, the CPB system exhibits regular optical hysteresis. Under a special condition, the Josephson effect and environmental effect can constructively interplay, revealing a negative the absorption coefficient of the fields. It leads to energy conversion from environmental fluctuations to coherent fields when implemented in a ring resonator.