Artificial atoms and quantum metamaterials: Watching a Schrödinger's cat

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Abstract

The current progress in design, fabrication and control of mesoscopic solid-state qubits provides tempting opportunities for the realization of quantum metamaterials – controllably quantum coherent artificial media. We discuss their possible technological applications and - more importantly - their significance in the context of a direct probing of the quantum-classical boundary.

1. Introduction

The experimental research in the field of quantum computing over the last decade led to the development of several types of solid state-based quantum bits, with steadily increasing decoherence times, controllability, and scalability. A number of essentially quantum effects were demonstrated on experiment, including quantum beats, Rabi oscillation, multiqubit entanglement and interaction with photon cavity modes. This led to a logical proposition of a *quantum* metamaterial [1], i.e., an artificial optical medium consisting of individually controllable quantum coherent elements ("artificial atoms"), the role of which can be played by, e.g., superconducting qubits. This is also seen as a logical direction of development for classical metamaterials [2]. Quantum metamaterials research would thus benefit from the convergence of two flourishing and dynamic research programs.

2. Artificial atoms in transmission lines and 1D and 2D quantum metamaterials

Recent experiments [3-5] showed that a superconducting qubit in a 1D transmission line behaves as an atom in free space with respect to its interaction with the electromagnetic field. Therefore the first order of business would be to realize 1D and 2D quantum metamaterials in microwave range using superconducting qubits as building blocks. We present here some theoretical predictions for the optical properties of such metamaterials and speculate on their technological applications. We shall also discuss what one would actually "see" when observing an extended quantum object, and whether these observation could shed light on the quantum-classical transition from a new angle.

3. Conclusion

Quantum metamaterials present a promising new field of research, both from the point of view of fundamental physics and applications. In particular, superconducting quantum metamaterials have the advantage of good theoretical understanding and advanced design, fabrication and experimental techniques, which make their realization feasible in near future. The next, more challenging, but rewarding, task will be to implement quantum metamaterials in the optical range. Then one hopes to see one day what a Schrödinger's cat actually looks like.

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