Transistor-Embedded Acousto-Optic and Nonlinear Metamaterials

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We present experimental results showing the application of transistor-embedded metamaterials to realize nonlinear and acousto-optic metamaterials. Due to their nonlinear properties, transistors can be used to realize a large variety of useful radio frequency (RF) functions and applications. These include switches, oscillators, amplifiers, tunable resistors and capacitors, and other devices. Metamaterials provide a natural platform for embedding circuit elements at RF to implement useful functionality. The useful properties of transistors can be exploited by embedding transistors within metamaterial unit cells. We will demonstrate how transistors allow the realization of acousto-optic and nonlinear metamaterials.

Transistors can be biased to operate in a number of regimes. For this work we focus on the linear regime of the transistor. In this bias range, we can consider the transistor to act as a controllable resistor in parallel with a capacitor, with tuning provided by a bias on the gate of the transistor. Embedding this within a metamaterial allows us to dynamically tune the resonant frequency and quality factor (Q) of the metamaterial by altering the gate bias of the transistor. By using an AC gate bias to tune the transistor, we can construct a nonlinear metamaterial. We demonstrate its nonlinearity by using the metamaterial as a mixer.

An acoustic signal incident on a transducer such as a piezoelectric membrane or microphone produces an AC voltage. We apply this voltage to the transistor bias. An incident acoustic signal will modulate the resonant frequency or Q of the metamaterial. We construct a wireless acousto-optic modulator using the nonlinear acousto-optic metamaterial and experimentally demonstrate its efficacy.