“Nonlinear rf SQUID Metamaterials: Have you Seen a Chimera?”

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Abstract:
Metamaterials are regular arrangements of designer “meta-atoms” that have engineered electromagnetic response in a frequency range of interest. Structures made up of collections of these atoms can create new optical and microwave phenomena, such as negative index of refraction and other extensions of Snell’s law, for example. My group has concentrated on harnessing the unique properties of superconductors to bring new features to metamaterials, including macroscopic quantum phenomena such as flux quantization and the Josephson effect. Our meta-atom is a superconducting loop completed with a single Josephson junction, historically known as an rf SQUID (radiofrequency superconducting quantum interference device). Through experiments, numerical simulations, and theory we explore the behavior of 2D rf SQUID metamaterials, which show extreme tunability and nonlinearity [1-4]. Typical resonant frequencies of the meta-atoms are in the 10 – 20 GHz range, and we have demonstrated dc-field tunability of up to 80 THz / Gauss [1]. Of primary concern is whether all of the meta-atoms work coherently to create a strong metamaterial response, or whether they wander off into other behavior such as the Chimera state [5]. To address this question we have developed a laser scanning microscope that images currents flowing in the SQUIDs while they are illuminated with both rf and dc flux at low temperatures. These images reveal a variety of collective responses that depend sensitively on experimental parameters. I will summarize our current understanding of the properties of this uniquely nonlinear medium, and discuss some potential applications.

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Bio Sketch:
Steven Anlage is Professor of Physics and faculty affiliate in Electrical and Computer Engineering and Materials Science and Engineering at the University of Maryland in the USA. His research covers experimental quantum/wave chaos utilizing overmoded microwave billiards. Ideas from wave chaos are applied to problems in electromagnetic interference in electrically-large structures. He developed a method to image the anisotropic nonlinear Meissner effect in superconductors and uses it to study the

pairing state symmetries of novel materials. His group also developed a nano-scale near-field microwave microscope to explore the local nonlinear properties of superconductors. His group developed the first superconducting metamaterials and has extensively studied a class of metamaterials based on the Josephson effect. In collaboration with theory groups he has created photonic topological insulators and excited uni-directional microwave signals that are topologically protected from back scattering. Prof. Anlage led a 12-member undergraduate Gemstone honors research team that was awarded the Best Paper Award in the 2016 IEEE Wireless Power Transfer Conference. In 2016 Professor Anlage was recognized as a University of Maryland Distinguished Scholar-Teacher, and in 2017 he won the University of Maryland Invention of the Year Award.