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Emergent Materials for Nonlinear Optoelectronics: The Marriage of Metamaterials and Wide Band Gap Semiconductors

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ABSTRACT

One of the goals of solid state physics is to wrestle new physical phenomena out of materials. In the early days, this was achieved by lowering the temperature of a pure element, where this approach lead to the discovery of the superconducting phase of mercury below 4K. As time marched on, physicists began to explore materials consisting of multiple elements from the periodic table (GaAs, SiC, etc.). Eventually, this lead to rather exotic combinations of materials, such as the superconducting cuprates, a metal oxide of all things. Eventually, physicists began to explore the effects of size and dimensionality on the physical properties of materials (nanomaterials, quantum well superlattices, etc.). The latter two approaches are alive and well today with graphene and topological materials, to name a few. All of the past and present discoveries can loosely be defined as emergent properties of materials, e.g., by lowering of the temperature of mercury, superconductivity emerges. The takeaway is that with ever increasing materials complexity, new phenomena emerges. The following question begs to be asked, "Is the road to emergent properties of materials only paved by new and unique combinations of elements of the periodic table?" My answer is no because we have another approach at our disposal, namely, integration of different classes of materials that have common ground and therefore can interact with one another. I will give an overview of our preliminary efforts to integrate metamaterials, specifically, plasmonic materials, with wide band gap semiconductors (ZnO, SnO, GaN, etc.). Both classes of materials are optically active and, therefore, can exchange energy via the absorption of photons or the injection/excitation of carriers. The motivation behind this effort is to create a hybrid material that operates in a metastable state, which in turn, produces emergent physics characteristics.

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